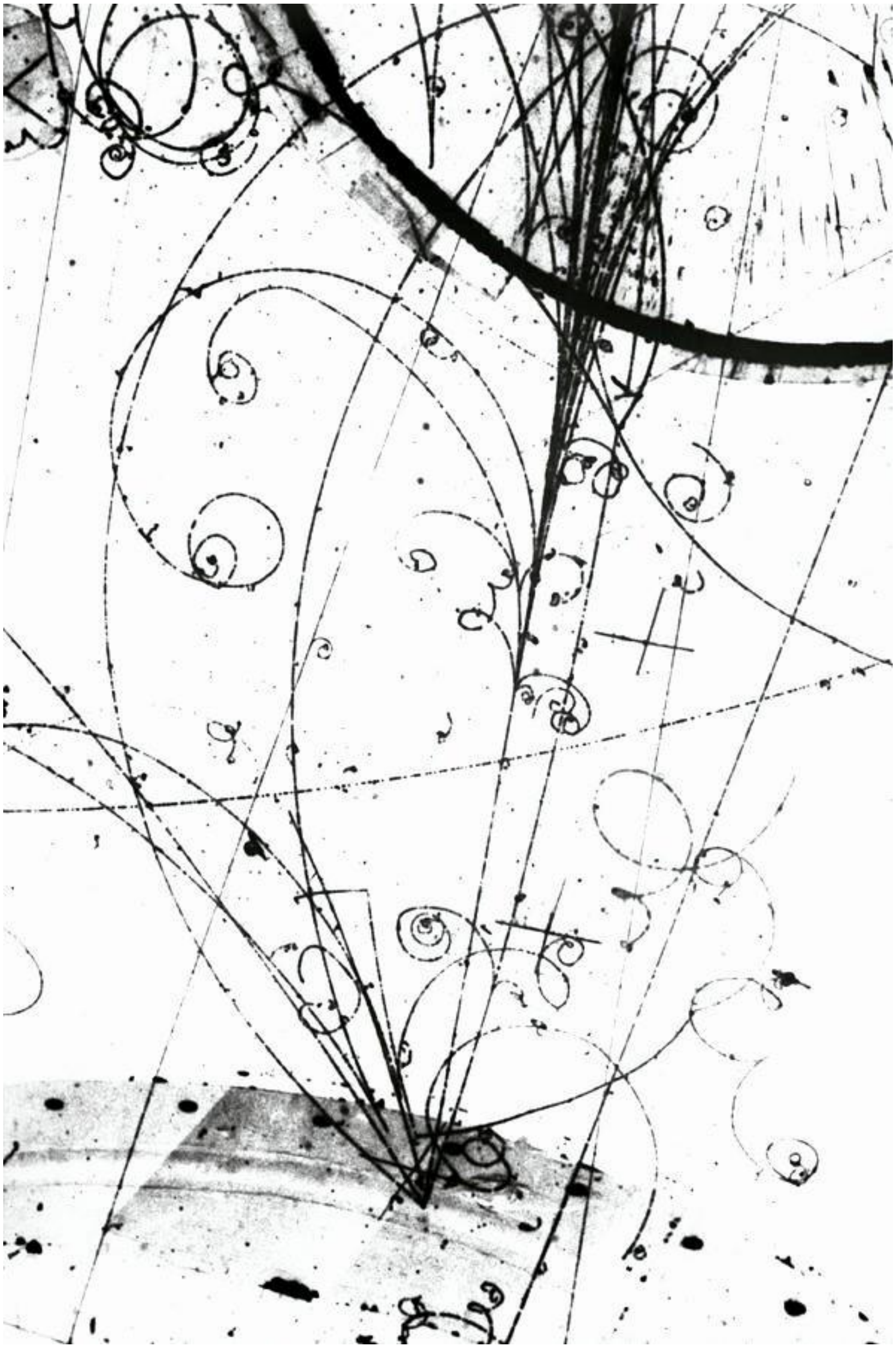
Science 10

Course Outcomes, Reference Material, and Review Questions



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2024 – 2025

Course Description

Students enrolled in *Science 10: Science for Sustainable Societies* will consider the integral roles science and technology play in their lives and communities. Throughout the course, students examine how scientific concepts and theories are applied to sustain the environmental limits of the natural resources we chemically transform and use as well as consider sustainability-related issues relevant to their lives.

The social and environmental contexts of advancement of science and technology are the central focus of the course. A contemporary approach for teaching physical sciences is applied so that students may become familiar with evolving theories and principles shaping how science is applied to design creative solutions. The connections that exist between matter and energy are explored.

Unit 1: Nuclear Theory and Technology

- **Unit 1.1**: Atomic Theory and Model of the Atom
  - Students will learn about the components and structure of an atom, atomic forces, isotopes, the fundamental particles of nature, and the creation of elements in stars.
  - Students will learn about the model of the atom from its earliest convention to contemporary models (the quantum mechanical model) and an introduction to electron arrangement in atoms including energy levels, sublevels, and atomic orbitals.

- **Unit 1.2**: The Periodic Table of the Elements
  - Students will learn why and how the elements are arranged in the periodic table. This will include an introduction to trends of physical and chemical properties, ionization energy, isotopes, and relative abundance of elements.

- **Unit 1.3**: Radioactive Atoms and Nuclear Reactions
  - Students will learn about harmful types of ionizing radiation including alpha, beta, and gamma radiation. This includes topics of background radiation, sources of radiation, half-life, and nuclear safety.
  - Students will learn about nuclear fusion, fission, and their applications incorporating the concept of the conservation of energy.

Unit 2: Chemistry Foundations

- **Unit 2.1**: Chemical Bonding
  - Students will learn about the formation of ionic, metallic, and covalent bonds.
  - Students will be able to write the formulas for ionic compounds and the names and formulas for two-element molecular compounds.
  - Students will learn about the properties associated with that type of bond to create the compound.

- **Unit 2.2**: The Mole and Chemical Reactions
  - Students will be introduced to the concept of the mole and apply Avogadro’s number to solve quantitative problems in chemistry.
  - Students will learn how to balance and complete simple chemical reactions, such as combination, decomposition, single displacement, double displacement, and combustion reactions. The concept of conservation of mass will be applied.
  - Students will be able to identify mole ratios from a balanced chemical reaction and apply them to solve problems.

Unit 3: Climate Change and Action (Science/Engineering Project)

The learning of climate change topics may be through a student-lead climate action project as opposed to formal teacher instruction. An introduction (or review) of climate science will be given based on the National Academy of Science publication *Climate Change: Evidence and Causes* (2020), *Climate Literacy: The Essential Principles of Climate Science* by The United States Global Change Research Program (2009), and *Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education*. Students will be given a physical or digital copy of all three resources. We will be exploring real data provided by NASA's climate change website, https://science.nasa.gov/climate-change/.

Within such a project students will demonstrate an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology (STSE). This will include relating their project to the United Nations Sustainability Development Goal 13 (Climate Action) and one of goal 7 (Affordable and Clean Energy), 9 (Industry, Innovation, and Infrastructure), or 12 (Responsible Consumption and Production).

Assessment for this unit will likely break down into multiple grades for *Science and Engineering Practices* and *Climate Science* as students develop, implement, and conclude their project. No matter what form this project takes, your science/engineering notebook and a digital scientific poster will be a major part of the evaluation. More details will be shared closer to the time of implementation, which will be towards the last month(s) of the course.

Final Assessment or Display of Learning

- 2-hour final assessment during assessment week in January.
- Weighted the same as semester unit assessments.
- A clear outline of topics to review and build for the final assessment will be provided.

Required Resources

- Scientific calculator
- Dedicated workbook for note taking and handouts.
- Dedicated bound or coiled workbook for course review questions.
- Dedicated science and engineering logbook
    - Bound or coiled with a paper size of 6.5" wide to 10.5" long.

Classroom Notes

- Nut and scent-free environment.
- Cell phones placed in dedicated space until told otherwise.
- No one should be back in corner that contains the electrical control switches.

Grade Scale – Each assessed outcome will use the following guide.

<table>
<tr><td rowspan="2">Expert: Demonstration of a deep/thorough understanding of the concept</td><td>6</td><td>Chose an appropriate strategy.
Successfully applied the necessary background skills and proper concepts to complete solutions.
Solutions contained no minor mistakes, or a summative contains at most two.
Clearly and concisely explained how to solve the problem using appropriate vocabulary, diagrams, and a coordinate system. “Did I show my work?”
Evaluated the reasonableness of my answer. “Does this make sense for the situation?”
Concept understood to a high degree to teach it to someone else.
Concept can be applied to new problems.</td></tr>
<tr><td>5</td><td>Chose an appropriate strategy.
Solution(s) contained an error(s) related to a background skill.
The concept can be explained using appropriate vocabulary.
The concept can be applied successfully in known problems.</td></tr>
<tr><td rowspan="2">Apprentice: Good/Satisfactory understanding of the concept</td><td>4</td><td>Chose an appropriate strategy.
A solution contained a concept error. A summative contained at most two such errors.
Minor mistakes and background skill errors are common.
Explanations of a problem contained mostly appropriate terminology.
Mistakes were identified and corrected after referring to a key.
More practice is needed solving this type of problem.</td></tr>
<tr><td>3</td><td>Chose an appropriate strategy.
Solution(s) contained a combination of concept errors, errors related to background skills and minor mistakes.
A lack of necessary background skills to solve problems.
Notes, examples, or help was needed to solve problems.
Explanations did not contain proper terminology.
Help from an expert is required solving this type of problem.</td></tr>
<tr><td rowspan="2">Novice: Minimal-to-no understanding of the concept</td><td>2</td><td>Incorrect strategy(ies) chosen for a problem(s).
Step-by-step instructions are required to solve problems.
Tasks could not be performed to an acceptable standard.
Consistent extra help from an expert is required.</td></tr>
<tr><td>1</td><td>Basics of what was needed to solve the problem were not known.
Solution left blank; first step not known.
Teaching by an expert is required.</td></tr>
</table>

Reassessing Units/Outcomes

One or two class days will be dedicated to for qualifying students to reassess a previous outcome. This will occur around mid-semester and towards the end of the semester. Note that a reassessment is the entire outcome, not just a question or two. Students can reassess any outcome to improve their grade and the highest grade is taken towards the mark calculation.

Determining a Percentage Mark

Learning Category	Overall Grade	Only shortly before report cards will a percentage mark be determined		
Expert	6	95 – 100		
	5	86	90	94
Apprentice	4	73	80	85
	3	60	66	72
Novice	2	50	56	59
	1	0	25	49

Students can track their progress and it will be placed in PowerSchool. The overall grade is guided with the calculation of the *median* and *mean* of all grades.

Overall Course Grade

- Calculate your *median* by arranging your grades from lowest to highest. The grade in the middle is *likely* your overall grade. If there is no exact middle number, average the two middle numbers.
- Calculate your mean by adding all the grades up and divide by how many there are.
- Use a pencil, if you are writing your grades here because grades will fluctuate over the semester.

Median = _______ Mean = _______

Example Percent Determinations

Median	Mean	Percent	Reason
4	3.8 – 4.2	80 %	Median and mean match or are close
	4.3 or higher	85 %	Mean is much higher than median
4	3.7 or lower	73 %	Mean is much lower than median

The Eight Science and Engineering Practices (NGSS)

Learning Target	Description
SEP1: Asking Questions and Defining Problems	A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world(s) works and which can be empirically tested. Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify ideas.
SEP2: Developing and Using Models	A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions, and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.
SEP3: Planning and Carrying Out Investigations	Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions.
SEP4: Analyzing and Interpreting Data	Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis. Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.
SEP5: Using Mathematics and Computational Thinking	In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions.
SEP6: Constructing Explanations and Designing Solutions	The end-products of science are explanations, and the end-products of engineering are solutions. The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.
SEP7: Engaging in Argument from Evidence	Argumentation is the process by which evidence-based conclusions and solutions are reached. In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to evaluate claims.
SEP8: Obtaining, Evaluating, and Communicating Information	Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to obtain information that is used to evaluate the merit and validity of claims, methods, and designs.

Lists of Ions, Prefixes, Acid Naming, and Common Hydrocarbons

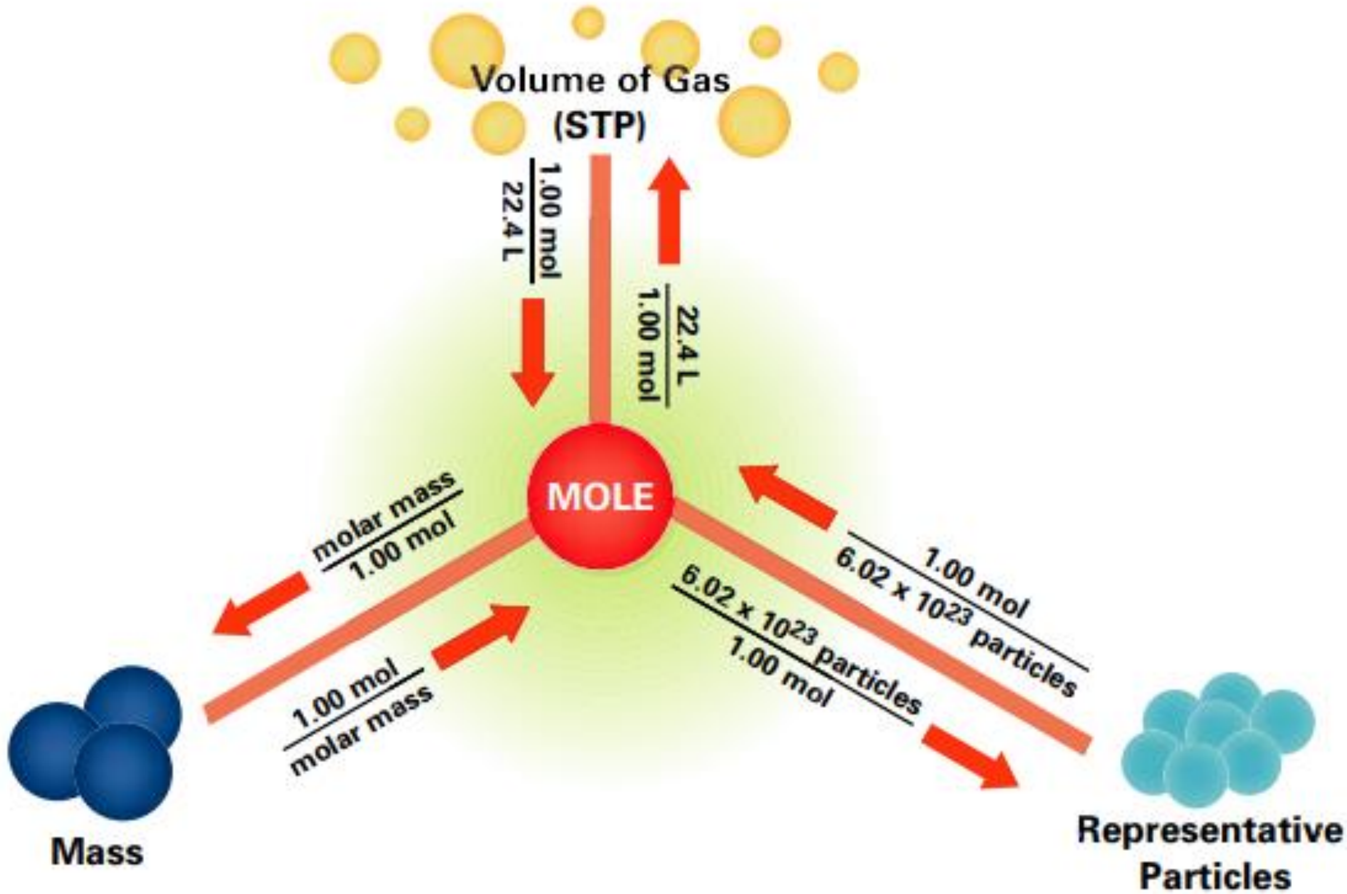
Cations	
Al^{3+}	Aluminum
NH_4^{1+}	Ammonium
Sb^{3+}	Antimony (III)
Sb^{5+}	Antimony (V)
Ba^{2+}	Barium
Be^{2+}	Beryllium
Bi^{3+}	Bismuth (III)
Bi^{5+}	Bismuth (V)
Cd^{2+}	Cadmium
Ca^{2+}	Calcium
Cs+	Cesium
Cr^{2+}	Chromium (II)
Cr^{3+}	Chromium (III)
Cu^{1+}	Copper (I)
Cu^{2+}	Copper (II)
Co^{2+}	Cobalt (II)
Co^{3+}	Cobalt (III)
H^{1+}	Hydrogen
Fe^{2+}	Iron (II)
Fe^{3+}	Iron (III)
Pb^{2+}	Lead (II)
Pb^{4+}	Lead (IV)
Li^{1+}	Lithium
Mg^{2+}	Magnesium
Mn^{2+}	Manganese (II)
Mn^{3+}	Manganese (III)
Hg^{2+}	Mercury
K^{1+}	Potassium
Ag^{1+}	Silver
Na^{1+}	Sodium
Sr^{2+}	Strontium
Sn^{2+}	Tin (II)
Sn^{4+}	Tin (IV)
Zn^{2+}	zinc

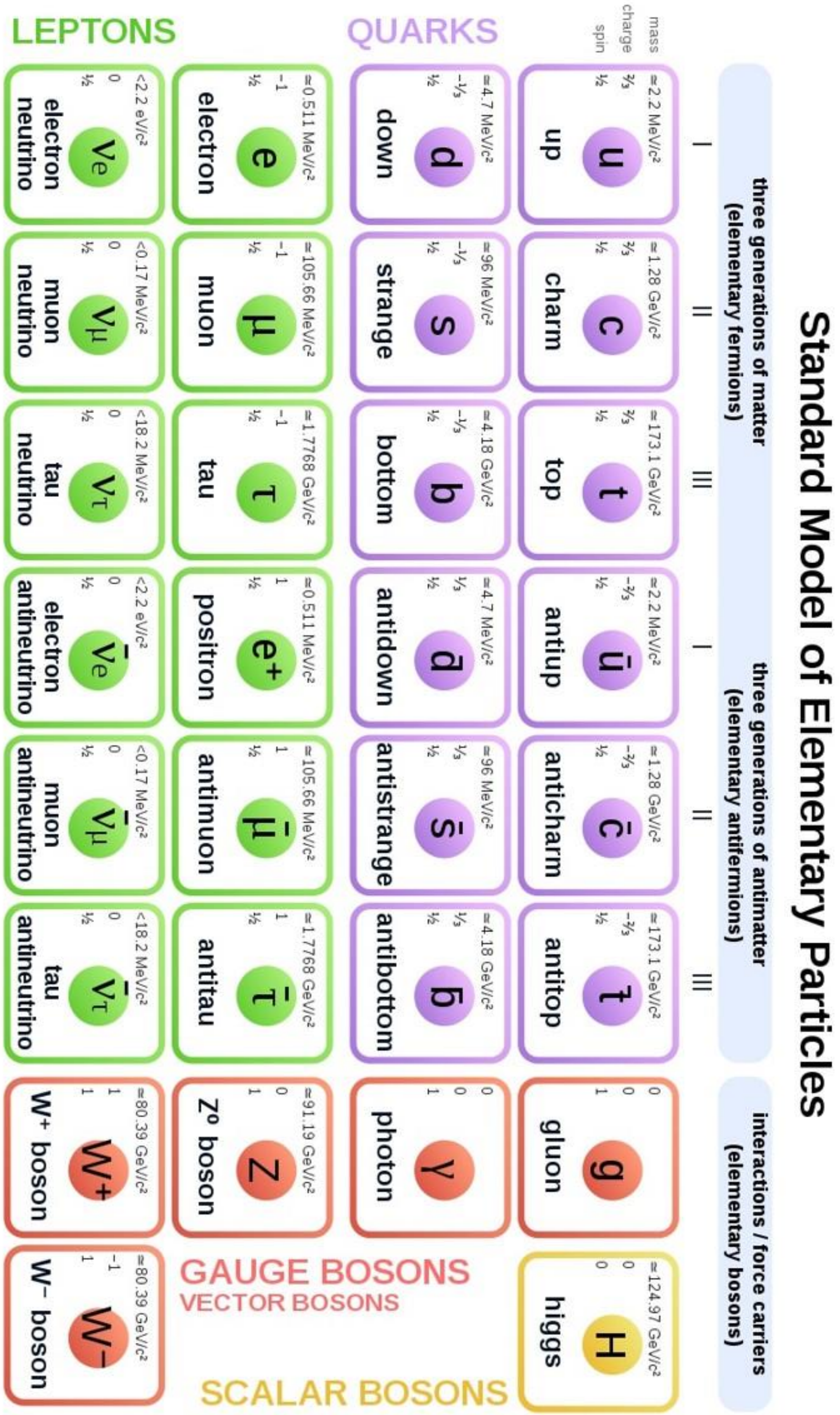
Anions	
$CH_3CO_2{}^{1-}$	Acetate
$HCO_3{}^{1-}$	Bicarbonate
Br^{1-}	Bromide
$CO_3{}^{2-}$	Carbonate
$ClO_3{}^{1-}$	Chlorate
Cl^{1-}	Chloride
$ClO_2{}^{-}$	Chlorite
$CrO_4{}^{2-}$	Chromate
CN^{1-}	Cyanide
NCO^{1-}	Cyanate
$Cr_2O_7{}^{2-}$	Dichromate
$H_2PO_4{}^{1-}$	Dihydrogen Phosphate
F^{1-}	Fluoride
OH^{1-}	Hydroxide
ClO^{1-}	Hypochlorite
I^{1-}	Iodide
$NO_3{}^{1-}$	Nitrate
N^{3-}	Nitride
$NO_2{}^{1-}$	Nitrite
O^{2-}	Oxide
$C_2O_4{}^{2-}$	Oxalate
$ClO_4{}^{1-}$	Perchlorate
$MnO_4{}^{1-}$	Permanganate
$O_2{}^{2-}$	Peroxide
$PO_4{}^{3-}$	Phosphate
P^{3-}	Phosphide
$PO_3{}^{3-}$	Phosphite
Se^{2-}	Selenide
$SO_4{}^{2-}$	Sulfate
S^{2-}	Sulfide
$SO_3{}^{2-}$	Sulfite
SCN^{1-}	Thiocyanate

Prefix	Name
1	Mono
2	Di
3	Tri
4	Tetra
5	Penta
6	Hexa
7	Hepta
8	Octa
9	Nona
10	Deca

Common Hydrocarbons	
Formula	Name
CH_4	Methane
C_2H_2	Ethene
C_2H_6	Ethane
C_3H_8	Propane
C_4H_{10}	Butane
C_5H_{12}	Pentane
C_6H_6	Benzene
C_6H_{14}	Hexane
C_7H_{16}	Heptane
C_8H_{18}	Octane
$C_6H_{12}O_6$	Glucose
$C_{12}H_{22}O_{11}$	Table Sugar

Mole Calculations





Standard Model of Elementary Particles
three generations of matter (elementary fermions)
three generations of antimatter (elementary antifermions)
interactions / force carriers (elementary bosons)
I
II
III
mass
charge
spin
QUARKS
LEPTONS
GAUGE BOSONS
VECTOR BOSONS
SCALAR BOSONS
≈2.2 MeV/c² ⅔ ½ u up
≈1.28 GeV/c² ⅔ ½ c charm
≈173.1 GeV/c² ⅔ ½ t top
≈2.2 MeV/c² −⅔ ½ ū antiup
≈1.28 GeV/c² −⅔ ½ c̄ anticharm
≈173.1 GeV/c² −⅔ ½ t̄ antitop
0 0 1 g gluon
≈124.97 GeV/c² 0 0 H higgs
≈4.7 MeV/c² −⅓ ½ d down
≈96 MeV/c² −⅓ ½ s strange
≈4.18 GeV/c² −⅓ ½ b bottom
≈4.7 MeV/c² ⅓ ½ d̄ antidown
≈96 MeV/c² ⅓ ½ s̄ antistrange
≈4.18 GeV/c² ⅓ ½ b̄ antibottom
0 0 1 γ photon
≈0.511 MeV/c² −1 ½ e electron
≈105.66 MeV/c² −1 ½ μ muon
≈1.7768 GeV/c² −1 ½ τ tau
≈0.511 MeV/c² 1 ½ e⁺ positron
≈105.66 MeV/c² 1 ½ μ̄ antimuon
≈1.7768 GeV/c² 1 ½ τ̄ antitau
≈91.19 GeV/c² 0 1 Z Z° boson
<2.2 eV/c² 0 ½ νe electron neutrino
<0.17 MeV/c² 0 ½ νμ muon neutrino
<18.2 MeV/c² 0 ½ ντ tau neutrino
<2.2 eV/c² 0 ½ ν̄e electron antineutrino
<0.17 MeV/c² 0 ½ ν̄μ muon antineutrino
<18.2 MeV/c² 0 ½ ν̄τ tau antineutrino
≈80.39 GeV/c² 1 1 W+ W+ boson
≈80.39 GeV/c² −1 1 W− W− boson

Introduction – Energy and Matter

1. In nature, what is energy?

2. What is Einstein's famous energy equation and what do the variables stand for?

3. What is the law of *conservation of energy*?

4. What is an example of mass being converted into energy?

5. What ***fundamental particles*** formed from energy during the first billionth of a second after the *Big Bang*?

6. The cosmic microwave background was energy released from what phenomena?

Unit 1.1 – Subatomic Particles, Atomic Forces, and the Creation of Elements

1. What is an atom?

2. What particles are contained within the nucleus of an atom?

3. In what area of an atom to electrons orbit the nucleus?

4. What is the size range of atoms in picometers, pm?

5. Describe the two factors that affect the size of atoms?

6. What is the trend in atomic size as you read the periodic table rows from left to right?

7. What is the trend in atomic size as you read the periodic table groups from top to bottom?

8. Why do atoms not necessarily get larger when the number of protons and electrons increase?

9. What is the radius of the nucleus compared to the radius of the atom?

10. What two factors keep the nucleus from blowing itself apart because like-charges repel each other?

11. In short, how do nuclear weapons release such immense quantities of energy?

12. List the four fundamental forces of nature.

13. What is the positive particle in the nucleus of an atom?

14. Suppose you have an atom that contains 6 neutrons and another atom that contains 7 neutrons. Are they different elements? Explain.

15. What is an isotope?

16. An element has three main properties: physical, chemical, and nuclear.
    a. What property(ies) are a result of the number of neutrons?
    b. What property(ies) are the result of the number of protons?

17. Why does a different number of protons usually mean different physical and chemical properties for elements?

18. What combination of quarks are protons made up of? Show how the quark charges add to give a charge of +1.

19. What is the purpose of gluons within a proton? Why are they so important?

20. What combination of quarks make up a neutron? Show that their partial electric charges add to be zero.

21. What is more massive, the neutron, proton, or electron?

22. What is the purpose of a neutron in a nucleus?

23. What is the mass number of carbon with 6 protons and 8 neutrons?

24. How many neutrons are in an atom of iron that has a mass number of 56?

25. What particles hold the quarks in a neutron together?

26. Is the charge of an electron positive, negative, or zero?

27. What type of fundamental particle is an electron? Describe the substructure of an electron.

28. What fundamental force keeps electrons in their orbits about the nucleus?

29. Describe electron orbitals.

30. How many electrons can be an orbital within an atom?

31. How many elementary particles are there in the standard model of particle physics?

32. When a particle collides with its antiparticle counterpart, what happens?

33. What is another name for the anti-electron?

34. Instead of kilograms to represent the mass of fundamental particles, what unit is used?

35. List the six types of quarks from most-to-least massive (not the anti-quarks).

36. What are the possible charges of leptons?

37. What lepton interacts extremely weakly with matter?

38. About how many electron neutrinos just passed through you?

39. Summarize the solar neutrino problem and how it was solved.

40. The gluon, photon, W and Z bosons carry what forces?

41. What boson is responsible for particles having mass?

42. What particles are affected by W and Z bosons?

43. What fundamental forces are only affective within the nucleus of an atom?

44. What distances are covered by the electromagnetic and gravitational forces?

45. What does a particle’s mass determine?

46. What research facility, and in what year, was the Higgs boson confirmed?

47. What is the maximum number of protons that the strong nuclear force can overcome?

48. What force can change quarks from one type to another?

49. List the four fundamental forces from strongest-to-weakest.

50. Where are elements more massive than hydrogen and helium created? Why does it have to be under those physical conditions.

51. Summarize the proton-proton chain 1 process.

52. Describe how the strong nuclear force contributes to the fusion of hydrogen to helium in the Sun.

53. Describe how the weak nuclear force contributes to the fusion of hydrogen to helium in the Sun.

54. How many gamma rays (highest energy electromagnetic radiation that ultimately give the Sun it’s high temperatures) are released in the formation of one helium-4 nucleus?

55. What is the highest atomic numbered element that can be fused in the life-cycle of a star?

56. How are all the other elements created if stellar-core fusion stops at iron?

Unit 1.1 – Atomic Models: Past to Present

1. Who was the Greek philosopher that guessed that all things were made of small, invisible bits called atoms?

2. When trying to come up with atomic theory, from the Greeks 2500 years ago, to Dalton and Schrödinger, what did that theory have to do to be accepted by the scientific community?

3. What were John Dalton’s four hypotheses of atomic theory in 1803?

4. What did J.J. Thompson invent to test matter for charges? What particle did he discover?

5. How did Thompson adjust the model of the atom?

6. Summarize the procedure of Earnest Rutherford's gold-foil experiment and the expected results if Thompson's model was correct.

7. What were the observations and conclusions of the gold-foil experiment?

8. When, and by whom, was the neutron discovered? Why was it not discovered until much later?

9. In the Rutherford model of the atom, where were electrons theorized to be in an atom?

10. What change did Niels Bohr make, through experiments with hydrogen, to Rutherford's model?

11. What does quantized mean, with respect to electrons in an atom?

12. Who provided a mathematical model of the atom in 1926?

13. What is the atomic orbital that Schrödinger discovered?

14. What is wave-particle duality?

15. What are sublevels in atoms?

16. How many electrons can exist in an atomic orbital?

17. What is the maximum number of electrons in each of the *s*, *p, d,* and *f*-sublevels?

18. The second energy level of an atom contains an s and p sublevel. What is the maximum number of electrons in the second energy level?

19. The third energy level of an atom contains an s, p, and d sublevel. What is the maximum number of electrons in the third energy level?

20. Why is the periodic table not presented as a uniform arrangement of the elements?

Unit 1.2 – The Periodic Table of the Elements

1. Use the periodic table to answer the following questions:
    a. What element is atomic number 78?
    b. How many electrons are there in the third energy level of Chromium, atomic number 24?
    c. What is the name of the element with 118 protons in its nucleus?
    d. How many neutrons in an atom of beryllium, atomic number 4?
    e. What is the average atomic mass barium, atomic number 56?
    f. How many electrons are there in the highest energy level of group 1 elements?
    g. Approximately, how many neutrons are there in an atom of Tungsten, atomic number 74?
    h. What is the name and symbol for the element with atomic number 40?
    i. What is the name and symbol for the element with atomic number 47?
    j. What element is in group 2, row 4?

2. What is an isotope?

3. Calculate the mass number for an atom of iron with 26 protons and 30 neutrons.

4. Calculate the number of neutrons in an atom of Tin that has a mass number of 120. Tin's atomic number is 50.

5. What is relative abundance when discussion elements?

6. What will happen to a nucleus if it is unstable?

7. What is the periodic law for elements on the periodic table?

8. What three general categories are the elements classified as on the periodic table?

9. Summarize the properties of metals.

10. Summarize the properties of nonmetals.

11. What makes metalloids different from metals and nonmetals?

12. The elements of what group(s) on the periodic table react violently with water?

13. Why does reactivity increase as you read down groups 1 and 2 on the periodic table?

14. What section of the periodic table contains many common metals like iron, zinc, gold, and platinum?

15. Describe the properties of the group 17 elements, the halogens.

16. Why does reactivity decrease as you read down group 17 elements?

17. Why do noble gases generally not react with other elements?

18. In general, what is the ionization energy of an electron?

19. As you read across the periods (the rows) of the periodic table, what is the general trend in ionization energy?

20. The electrons of what element have the highest ionization energy?

21. The electrons of what element have the lowest ionization energy?

22. As you read down groups 1, 2, 15 - 18 of the periodic table, what is the trend in ionization energy?

Unit 1.3 – Radioactive Atoms and Nuclear Reactions

1. What are the different parts of the electromagnetic spectrum?

2. Define what it means for the nuclei of atoms to be radioactive.

3. What are the three possible reasons radioactive nuclei are unstable and will undergo radioactive decay?

4. What is a radioisotope?
5. Define half-life as relating to radioactive decay.
6. Explain the process that gets C-14 into the various materials.
7. What are the six main ways an unstable nucleus could undergo radioactive decay?
8. Briefly describe the penetrating power of radiation types.
9. What makes a nucleus stable considering particle emitting radioactive decay?
10. What is an alpha particle?
11. What conditions of a nucleus likely result in alpha decay?
12. Write the nuclear equation for the alpha decay of Pb-183 (Pb is lead, atomic number 82).
13. Write the nuclear equation for the alpha decay of Rn-215 (Rn is radon, atomic number 86).
14. What element alpha decays into W-162 (W is tungsten, atomic number 74)? Write the nuclear equation for this radioactive decay.
15. What element alpha decays into Ce-140 (Ce is cerium, atomic number 58)? Write the nuclear equation for this radioactive decay.
16. What objects can stop an alpha particle emitted from radioactive decay?
17. How are alpha decaying atoms dangerous to life forms?
18. What possible radioactive particles are emitted during beta decay.
19. Describe the beta-minus radioactive decay process.
20. Describe the beta-plus radioactive decay process.
21. What is the role of the weak nuclear force in both types of beta decay?
22. Write the nuclear reaction for the beta-minus decay of Cl-42 (Cl is chlorine, atomic number 17).
23. Write the nuclear reaction for the beta-plus decay of Cl-33.
24. Write the nuclear reaction for the beta-plus decay of Cr-46 (Cr is chromium, atomic number 24).
25. Write the nuclear reaction for the beta-minus decay of Al-29 (Al is aluminum, atomic number 13).
26. A type of decay created Mn-52 and a positron (Mn is manganese, atomic number 25). Write the nuclear reaction.

27. A type of decay created S-46 and an electron anti-neutrino (S is sulfur, atomic number 16). Write the nuclear reaction.

28. A W^+ boson decayed into a positron and an electron neutrino in the formation of K-38 (K is potassium, atomic number 19). Write the nuclear reaction.

29. A W^- boson decayed into an electron and an electron anti-neutrino in the formation of Co-59 (Co is cobalt, atomic number 27). Write the nuclear reaction.

30. What are the dangers to organisms if they are exposed to a high dose of beta radiation?

31. Describe the process that results in the gamma decay of a nucleus.

32. What are the dangers of gamma radiation?

33. What are radioactive tracers in nuclear medicine?

34. Summarize the diagnostic uses of Tc-99, Th-201, I-131, and Na-24.

35. Explain how a smoke detector works using a source of radioactive Am-241.

36. In general, what is nuclear fusion?

37. Why do nuclei have to be moving at very high speeds for nuclear fusion to occur?

38. Where is the primary source of nuclear fusion in the universe?

39. What are the reactants and products of experimental nuclear fusion on Earth?

40. With extremely high temperatures needed, what is used to contain the hydrogen plasma required for earth-based nuclear fusion?

41. Briefly describe the work done at the JET and NIF laboratories in the UK and US, respectively.

42. What uranium isotope is used in nuclear fission?

43. Describe the process of splitting one U-235 atom.

44. Why are slow moving neutrons used in nuclear fission?

45. Per mole of U-235, how much mass has been released as energy?

46. If the nucleons are conserved in the fission process, what mass is converted into energy?

47. What is meant by the binding energy of a nucleus?

48. How is the difference of binding energy released in the nuclear fission process?

49. Describe nuclear reactions and binding energy as the mass number increases.

50. What is a chain reaction?

51. Define critical, subcritical, and supercritical mass as it relates to nuclear fission.

52. What fissionable materials are used in atomic weapons?

53. Summarize how the atomic bomb, Little Boy, worked to create a nuclear explosion.

54. About how many people died from the atomic bomb dropped on Hiroshima? Were all those deaths instantaneous?

55. Ghostly reminders of nuclear bombs, how were the nuclear shadows created in Hiroshima?

56. Summarize the workings of the atomic bomb, Fat Man.

57. Why was the destruction of Nagasaki so complete?

58. Briefly summarize how a nuclear reactor works to create electricity.

59. List and describe the five minimum components to a nuclear reactor.

60. How much energy is in one uranium pellet compared to coal and oil?

61. What are the two main types of accidents that have happened at a nuclear reactor?

62. Describe the nuclear accident that happened at Three Mile Island in Pennsylvania in 1979.

63. Chernobyl, 1986 saw a nuclear accident during an unauthorized experiment. Summarize the accident and its effects on the local area.

64. Summarize what caused, and the aftermath of the nuclear accident at the Fukushima Daiichi nuclear plant in Japan on March 11^{th}, 2011.

65. How is Pu-239 formed during the fission process of U-235?

66. Pu-239 is radioactive mainly through alpha decay, why is Pu-239 so dangerous to humans when alpha particles are blocked by a sheet of paper?

67. What are some of the products found in spent fuel rods?

68. What are transuranium elements and why are they likely dangerous?

69. Summarize how nuclear waste is stored in Canada.

70. Nuclear energy is described as clean energy. Why is it called clean energy?

71. In 2020, how many kilograms of carbon dioxide was kept out of the atmosphere in the United States by using nuclear power?

72. Go to the following link, https://www.nbpower.com/en/about-us/our-business/nuclear/, and answer the following questions about New Brunswick's Point Lepreau Nuclear Generating Station.
    a. What year was it commissioned?
    b. What is the gross station output?
    c. What does it use as a moderator?
    d. What is the type of fuel?
    e. How many coolant pumps and steam generators?
    f. What does it use a coolant?
    g. What is the steam temperature?

Unit 2.1 – Chemical Bonding: Ionic, Molecular, and Metallic Bonds

1. What is an ion?

2. How are ionic compounds held together?

3. Name the following monatomic or polyatomic ions:
    a. Ca^{2+}
    b. Al^{3+}
    c. P^{3-}
    d. S^{2-}
    e. Sn^{4+}
    f. Cu^{2+}
    g. N^{3-}
    h. PO_4^{3-}
    i. NH_4^{+}
    j. OH^{-}
    k. SO_3^{2-}
    l. NO_2^{-}

4. Write the formula unit for the following ionic compounds given their name:
    a. Potassium Nitride
    b. Aluminum Sulfide
    c. Magnesium Nitrate
    d. Iron (III) Phosphide
    e. Tin (IV) Oxide
    f. Tin (II) Bromide
    g. Calcium Chlorate
    h. Strontium Selenide
    i. Zinc Hydroxide
    j. Lead (II) Dichromate
    k. Cobalt (II) thiocyanate
    l. Ammonium Phosphite

5. What is a metallic bond? Use that to explain how a piece of metal, like iron, can stay together as a solid?

6. What is happening at the atomic level to explain why metals are ductile and malleable?

7. What is an alloy and why are they important?

8. How are molecular compounds held together?

9. Write the formula for the following molecular compounds.
    a. Tricarbon dioxide
    b. Tetranitrogen monoxide
    c. Phosphorus trifluoride
    d. Pentaiodine hexachloride

10. Write the name of the following molecular compounds using the prefixes covered in class.
    a. S_3O_8
    b. N_2Br
    c. C_2N_2
    d. P_8O_3

11. Summarize the characteristics of ionic and molecular compounds. You can answer in a table format, similar to what was given in the class notes.

Unit 2.2 – The Mole and Chemical Reactions

1. Calculate the molar mass of each of the following compounds.
    - C_7H_{14}
    - Fe_2O_3
    - $C_6H_{12}O_6$
    - Na_2SO_3
    - $Sn_3(PO_4)_4$

2. How many moles is 7.84×10^{24} atoms of carbon?

3. How many atoms are in 29.4 moles of titanium?

4. How many moles is 8.12×10^{25} molecules of water?

5. How many molecules are in 75.6 mol P_2O_4?

6. Calculate the mass of 45.1 mol FeO.

7. A sample of C_4H_{10} has a mass 498 g. How many moles is this?

8. How many molecules are in a 548 g sample of H_2O?

9. How many total atoms in 238 moles of $Ba_3(PO_4)_2$?

10. A sample of $HgCO_3$ contains 6.14×10^{24} formula units (particles). Calculate the sample's mass.

11. How many atoms of nitrogen in 64.2 mol of $Fe(NO_3)_3$?

12. Consider the word equation: Calcium Carbonate + Oxygen → Calcium Oxide + Carbon Dioxide
    a. List the reactants.
    b. List the products.

13. What is the law of the conservation of mass?

14. When a log burns in a fire, the ashes have a much lower mass than the log. Explain.

15. What is the difference between a skeleton equation and a balanced chemical equation?

16. Balance the following skeleton equations (copy them into your answer book):

    a. K_2O + H_2O → KOH
    b. CaO + HCl → $CaCl_2$ + H_2O
    c. KI + Cl_2 → KCl + I_2
    d. KI + H_2O_2 → KOH + I_2
    e. KF + $BaBr_2$ → BaF_2 + KBr
    f. N_2H_4 + O_2 → H_2O + N_2
    g. Cu_2O + HCl → CuCl + H_2O
    h. W + Cl_2 → WCl_3
    i. Fe_2O_3 → Fe + O_2
    j. Al_2O_3 + C + Cl_2 → CO + $AlCl_3$
    k. $AlBr_3$ → Al + Br_2
    l. ZnO + HF → H_2O + ZnF_2
    m. $NaClO_3$ → NaCl + O_2
    n. Rb_2SO_4 + $Pb_3(PO_4)_4$ → Rb_3PO_4 + $Pb(SO_4)_2$
    o. $(NH_4)_2S$ + $Pb(NO_3)_2$ → NH_4NO_3 + PbS

17. Label each equation in question #16 as combination, decomposition, single displacement, double displacement, combustion, or other.

18. For each of the chemical reactions below:
    - Label it as combination, decomposition, single displacement, double displacement.
    - Complete the reaction by writing the products.
    - Balance the reaction to show the conservation of mass.

    a. Al + O_2 →
    b. Zn + $CuSO_4$ →
    c. CaO →
    d. H_2 + Cl_2 →
    e. $AgNO_3$ + NaCl →
    f. K_2O →
    g. Al + Fe_2O_3 →
    h. Ca + Cl_2→
    i. $Ca(OH)_2$ + H_3PO_4 →
    j. $BaCl_2$ + H_2SO_4 →

19. Write out the balanced chemical equation for the complete combustions of:
    a. Propane
    b. Butane
    c. Heptane
    d. Octane

For questions 20 - 24, use the following balanced combustion of propanol. The numbers in brackets are the molar masses of the reactants and products.

Propanol (60g) + Oxygen (32g) → Carbon Dioxide (44g) + Water (18g)

$$2C_3H_8O + 9O_2 \rightarrow 6CO_2 + 8H_2O$$

20. Calculate number of moles of water produced if 23.5 mol of propanol is consumed.

21. If 12.5 mol of carbon dioxide was produced in the chemical reaction, how many moles of water was produced?

22. Calculate the number of moles of oxygen required to combust 81 moles of propanol.

23. Calculate the mass of oxygen used up if 42 mol of water is produced in the reaction.

24. Calculate the mass of water produced when 12.8 mol of propanol is combusted.


13 CLIMATE ACTION
13.1 Strengthen resilience and adaptive capacity to climate-related disasters
13.2 Integrate climate change measures into policies and planning
13.3 Build knowledge and capacity to meet climate change
13.a Implement the UNFCCC
13.b Promote mechanisms to raise capacity for climate planning and management
1 NO POVERTY
2 ZERO HUNGER
11 SUSTAINABLE CITIES AND COMMUNITIES
3 GOOD HEALTH AND WELL-BEING
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
14 LIFE BELOW WATER
15 LIFE ON LAND
4 QUALITY EDUCATION
8 DECENT WORK AND ECONOMIC GROWTH
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
5 GENDER EQUALITY
10 REDUCED INEQUALITIES

Nobel Prize Laureates and Other Experts Issue Urgent Call for Action After 'Our Planet, Our Future' Summit

Statement | April 29, 2021

Our Planet, Our Future
An Urgent Call for Action

This statement was inspired by the discussions at the 2021 Nobel Prize Summit, issued by the Steering Committee and co-signed by Nobel Laureates and experts.

Preamble

The Nobel Prizes were created to honor advances of "the greatest benefit to humankind." They celebrate successes that have helped build a safe, prosperous, and peaceful world, the foundation of which is scientific reason.

"Science is at the base of all the progress that lightens the burden of life and lessens its suffering." Marie Curie (Nobel Laureate 1903 and 1911)

Science is a global common good on a quest for truth, knowledge, and innovation toward a better life. Now, humankind faces new challenges at unprecedented scale. The first Nobel Prize Summit comes amid a global pandemic, amid a crisis of inequality, amid an ecological crisis, amid a climate crisis, and amid an information crisis. These supranational crises are interlinked and threaten the enormous gains we have made in human progress. It is particularly concerning that the parts of the world projected to experience many of the compounding negative effects from global changes are also home to many of the world's poorest communities, and to indigenous peoples. The summit also comes amid unprecedented urbanization rates and on the cusp of technological disruption from digitalization, artificial intelligence, ubiquitous sensing and biotechnology and nanotechnology that may transform all aspects of our lives in coming decades.

"We have never had to deal with problems of the scale facing today's globally interconnected society. No one knows for sure what will work, so it is important to build a system that can evolve and adapt rapidly." Elinor Ostrom (Nobel Laureate 2009)

The summit has been convened to promote a transformation to global sustainability for human prosperity and equity. Time is the natural resource in shortest supply. The next decade is crucial: Global greenhouse gas emissions need to be cut by half and destruction of nature halted and reversed. An essential foundation for this transformation is to address destabilizing inequalities in the world. Without transformational action this decade, humanity is taking colossal risks with our common future. Societies risk large-scale, irreversible changes to Earth's biosphere and our lives as part of it.

"A new type of thinking is essential if mankind is to survive and move toward higher levels." Albert Einstein (Nobel Laureate 1921)

We need to reinvent our relationship with planet Earth. The future of all life on this planet, humans and our societies included, requires us to become effective stewards of the global commons — the climate, ice, land, ocean, freshwater, forests, soils, and rich diversity of life that regulate the state of the planet, and combine to create a unique and harmonious life-support system. There is now an existential need to build economies and societies that support Earth system harmony rather than disrupt it.

Our Planet

"It seems appropriate to assign the term 'Anthropocene' to the present." Paul Crutzen (Nobel Laureate 1995)

Geologists call the last 12,000 years the Holocene epoch. A remarkable feature of this period has been relative Earth-system stability. But the stability of the Holocene is behind us now. Human societies are now the prime driver of change in Earth's living sphere — the biosphere. The fate of the biosphere and human societies embedded within it is now deeply intertwined and evolving together. Earth has entered a new geological epoch, the Anthropocene. Evidence points to the 1950s as the onset of the Anthropocene — a single human lifetime ago. The Anthropocene epoch is more likely to be characterized by speed, scale, and shock at global levels.

Planetary health

The health of nature, our planet, and people is tightly connected. Pandemic risk is one of many global health risks in the Anthropocene. The risks of pandemics are now greater due to destruction of natural habitats, highly networked societies, and misinformation.

The COVID-19 pandemic is the greatest global shock since the Second World War. It has caused immense suffering and hardship. The scientific response in the face of catastrophe, from detection to vaccine development, has been robust and effective. There is much to applaud. However, there have been clear failings. The poorest and most marginalized in societies remain the most vulnerable. The scale of this catastrophe could have been greatly reduced through preventive measures, greater openness, early detection systems, and faster emergency responses.

Reducing risk of zoonotic disease like COVID-19 requires a multi-pronged approach recognizing "one health" — the intimate connections between human health and the health of other animals and the environment. Rapid urbanization, agricultural intensification, overexploitation, and habitat loss of large wildlife all promote the abundance of small mammals, such as rodents. Additionally, these land-use changes lead animals to shift their activities from natural ecosystems to farmlands, urban parks, and other human-dominated areas, greatly increasing contact with people and the risk of disease transmission.

The global commons

Global heating and habitat loss amount to nothing less than a vast and uncontrolled experiment on Earth's life-support system. Multiple lines of evidence now show that, for the first time in our existence, our actions are destabilizing critical parts of the Earth system that determine the state of the planet.

For 3 million years, global mean temperature increases have not exceeded 2°C of global warming, yet that is what is in prospect within this century. We are on a path that has taken us to 1.2°C warming so far — the warmest temperature on Earth since we left the last ice age some 20,000 years ago, and which will take us to >3°C warming in 80 years.

At the same time, we are losing Earth resilience, having transformed half of Earth's land outside of the ice sheets, largely through farming expansion. Of an estimated 8 million species on Earth, about 1 million are under threat. Since the 1970s, there has been an estimated 68% decline in the populations of vertebrate species.

Inequality

"The only sustainable prosperity is shared prosperity." Joseph Stiglitz (Nobel Laureate 2001)

While all in societies contribute to economic growth, the wealthy in most societies disproportionately take the largest share of this growing wealth. This trend has become more pronounced in recent decades. In highly unequal societies, with wide disparities in areas such as health care and education, the poorest are more likely to remain trapped in poverty across several generations.

More equal societies tend to score highly on metrics of well-being and happiness. Reducing inequality raises social capital. There is a greater sense of community and more trust in government. These factors make it easier to make collective, long-term decisions. Humanity's future depends on the ability to make long-term, collective decisions to navigate the Anthropocene.

The COVID-19 pandemic, the largest economic calamity since the Great Depression, is expected to worsen inequality at a moment when inequality is having a clear destabilizing political impact in many countries. Climate change is expected to further exacerbate inequality. Already, the poorest, often living in vulnerable communities, are hit hardest by the impacts of climate, and live with the damaging health impacts of energy systems, for example air pollution. Furthermore, although urbanization has brought many societal benefits, it is also exacerbating existing, and creating new, inequities.

It is an inescapable conclusion that inequality and global sustainability challenges are deeply linked. Reducing inequality will positively impact collective decision-making.

Technology

Technology

The accelerating technological revolution — including information technology, artificial intelligence, and synthetic biology — will impact inequality, jobs, and entire economies, with disruptive consequences. On aggregate, technological advancements so far have accelerated us down the path toward destabilizing the planet. Without guidance, technological evolution is unlikely to lead to transformations toward sustainability. It will be critical to guide the technological revolution deliberately and strategically in the coming decades to support societal goals.

Acknowledging urgency and embracing complexity

The future habitability of Earth for human societies depends on the collective actions humanity takes now. There is rising evidence that this is a decisive decade (2020-2030). Loss of nature must be stopped and deep inequality counteracted. Global emissions of greenhouse gases need to be cut by half in the decade of 2021-2030. This alone requires collective governance of the global commons — all the living and non-living systems on Earth that societies use but that also regulate the state of the planet — for the sake of all people in the future.

On top of the urgency, we must embrace complexity. Humanity faces rising network risks and cascading risks as human and technological networks grow. The 2020/2021 pandemic was a health shock that quickly cascaded into economic shocks. We must recognize that surprise is the new normal and manage for complexity and emergent behavior.

Our Future

A decade of action

Time is running out to prevent irreversible changes. Ice sheets are approaching tipping points — parts of the Antarctic ice sheet may have already crossed irreversible tipping points. The circulation of heat in the North Atlantic is unequivocally slowing down due to accelerated ice melt. This may further affect monsoons and the stability of major parts of Antarctica. Rainforests, permafrost, and coral reefs are also approaching tipping points. The remaining carbon budget for a 67% probability of not exceeding 1.5°C global warming will be exhausted before 2030. At the same time, every week until 2050, the urban population will increase by about 1.3 million, requiring new buildings and roads, water and sanitation facilities, and energy and transport systems. The construction and operation of these infrastructure projects will be energy and emissions intensive unless major changes are made in how they are designed and implemented.

In 2021, major summits will generate political and societal momentum for action on climate, biodiversity, food systems, desertification, and the ocean. In 2022, the Stockholm+50 event marks the 50th anniversary of the first Earth Summit. This is an important opportunity to reflect on progress to meet the United Nations Sustainable Development Goals (SDGs), due to be completed by 2030. Yet a disconnect exists between the urgency indicated by the empirical evidence and the response from electoral politics: The world is turning too slowly.

Planetary stewardship

“We must break down the walls that have previously kept science and the public apart and that have

encouraged distrust and ignorance to spread unchecked. If anything prevents human beings from rising to the current challenge, it will be these barriers." Jennifer Doudna (Nobel Laureate 2020)

Effective planetary stewardship requires updating our Holocene mindset. We must act on the urgency, the scale, and the interconnectivity between us and our home, planet Earth. More than anything, planetary stewardship will be facilitated by enhancing social capital — building trust within societies and between societies.

Is a new worldview possible? 193 nations have adopted the SDGs. The global pandemic has contributed to a broader recognition of global interconnectivity, fragility, and risk. Where they possess the economic power to do so, more people are increasingly making more sustainable choices regarding transportation, consumption, and energy. They are often ahead of their governments. And increasingly, the sustainable options, for example solar and wind power, are similar in price to fossil fuel alternatives or cheaper — and getting cheaper.

The question at a global systems level today is not whether humanity will transition away from fossil fuels. The question is: Will we do it fast enough? Solutions, from electric mobility to zero-carbon energy carriers and sustainable food systems, are today often following exponential curves of advancement and adoption. How do we lock this in? The following seven proposals provide a foundation for effective planetary stewardship.

- POLICY: Complement GDP as a metric of economic success with measures of true well-being of people and nature. Recognize that increasing disparities between rich and poor feed resentment and distrust, undermining the social contract necessary for difficult, long-term collective decision-making. Recognize that the deteriorating resilience of ecosystems undermines the future of humanity on Earth.
- MISSION-DRIVEN INNOVATION: Economic dynamism is needed for rapid transformation. Governments have been at the forefront of funding transformational innovation in the last 100 years. The scale of today's challenges will require large-scale collaboration between researchers, government, and business — with a focus on global sustainability.
- EDUCATION: Education at all ages should include a strong emphasis on the nature of evidence, the scientific method, and scientific consensus to ensure future populations have the grounding necessary to drive political and economic change. Universities should embed concepts of planetary stewardship in all curricula as a matter of urgency. In a transformative, turbulent century, we should invest in life-long learning, and fact-based worldviews.
- INFORMATION TECHNOLOGY: Special interest groups and highly partisan media can amplify misinformation and accelerate its spread through social media and other digital means of communication. In this way, these technologies can be deployed to frustrate a common purpose and erode public trust. Societies must urgently act to counter the industrialization of misinformation and find ways to enhance global communication systems in the service of sustainable futures.
- FINANCE AND BUSINESS: Investors and companies must adopt principles of recirculation and

regeneration of materials and apply science-based targets for all global commons and essential ecosystem services. Economic, environmental, and social externalities should be fairly priced.

- SCIENTIFIC COLLABORATION: Greater investment is needed in international networks of scientific institutions to allow sustained collaboration on interdisciplinary science for global sustainability as well as transdisciplinary science that integrates diverse knowledge systems, including local, indigenous, and traditional knowledge.
- KNOWLEDGE: The pandemic has demonstrated the value of basic research to policymakers and the public. Commitment to sustained investment in basic research is essential. In addition, we must develop new business models for the free sharing of all scientific knowledge.

Conclusion

Global sustainability offers the only viable path to human safety, equity, health, and progress. Humanity is waking up late to the challenges and opportunities of active planetary stewardship. But we *are* waking up. Long-term, scientifically based decision-making is always at a disadvantage in the contest with the needs of the present. Politicians and scientists must work together to bridge the divide between expert evidence, short-term politics, and the survival of all life on this planet in the Anthropocene epoch. The long-term potential of humanity depends upon our ability today to value our common future. Ultimately, this means valuing the resilience of societies and the resilience of Earth's biosphere.

Signatures

Brian Schmidt,* Australian National University
William E. Moerner,* Stanford University
Linda Buck,* Fred Hutchinson Cancer Research Center
Diana Liverman, University of Arizona
Elizabeth H. Blackburn,* University of California, San Francisco
Thomas Lovejoy, United Nations Foundation
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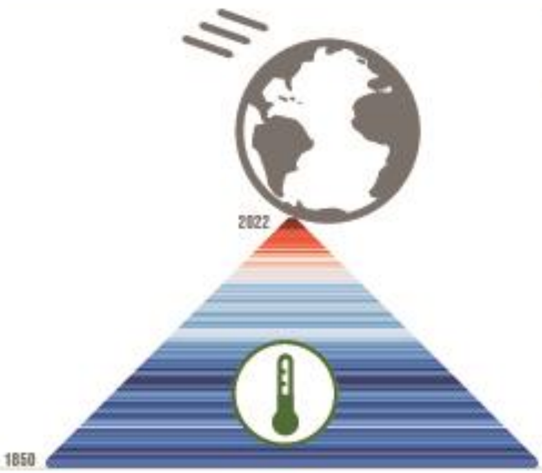
Simon Levin, Princeton University
Oliver Hart,* Harvard University
Lisen Schultz, Stockholm Resilience Centre, Stockholm University
Magdalena Skipper, *Nature*
Eric Lambin, Stanford University
Joern Fischer, Leuphana University
Frank Geels, Manchester University

TAKE URGENT ACTION TO COMBAT CLIMATE CHANGE AND ITS IMPACTS

13 CLIMATE ACTION

EARTH'S TIPPING POINT

STANDING AT THE BRINK OF CLIMATE CALAMITY



WHERE WE ARE

THE WORLD WILL EXCEED 1.5°C BY 2035 AND FACES A 2.5°C WARMING BY 2100

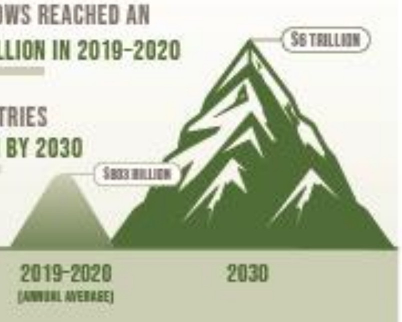
WHAT WE NEED

DEEP, RAPID AND SUSTAINED GHG EMISSION REDUCTIONS BY 43% BY 2030 AND TO NET ZERO BY 2050

BILLIONS TO TRILLIONS:

GLOBAL CLIMATE FINANCE FLOWS REACHED AN ANNUAL AVERAGE OF $803 BILLION IN 2019-2020

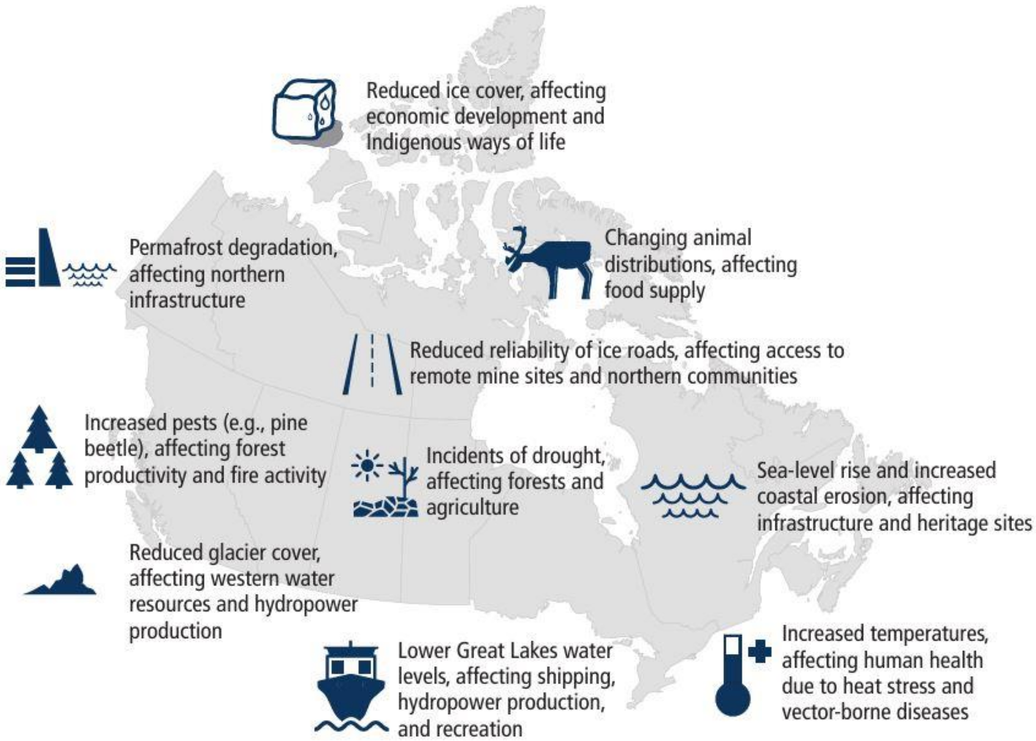
HOWEVER, DEVELOPING COUNTRIES REQUIRE NEARLY $6 TRILLION BY 2030

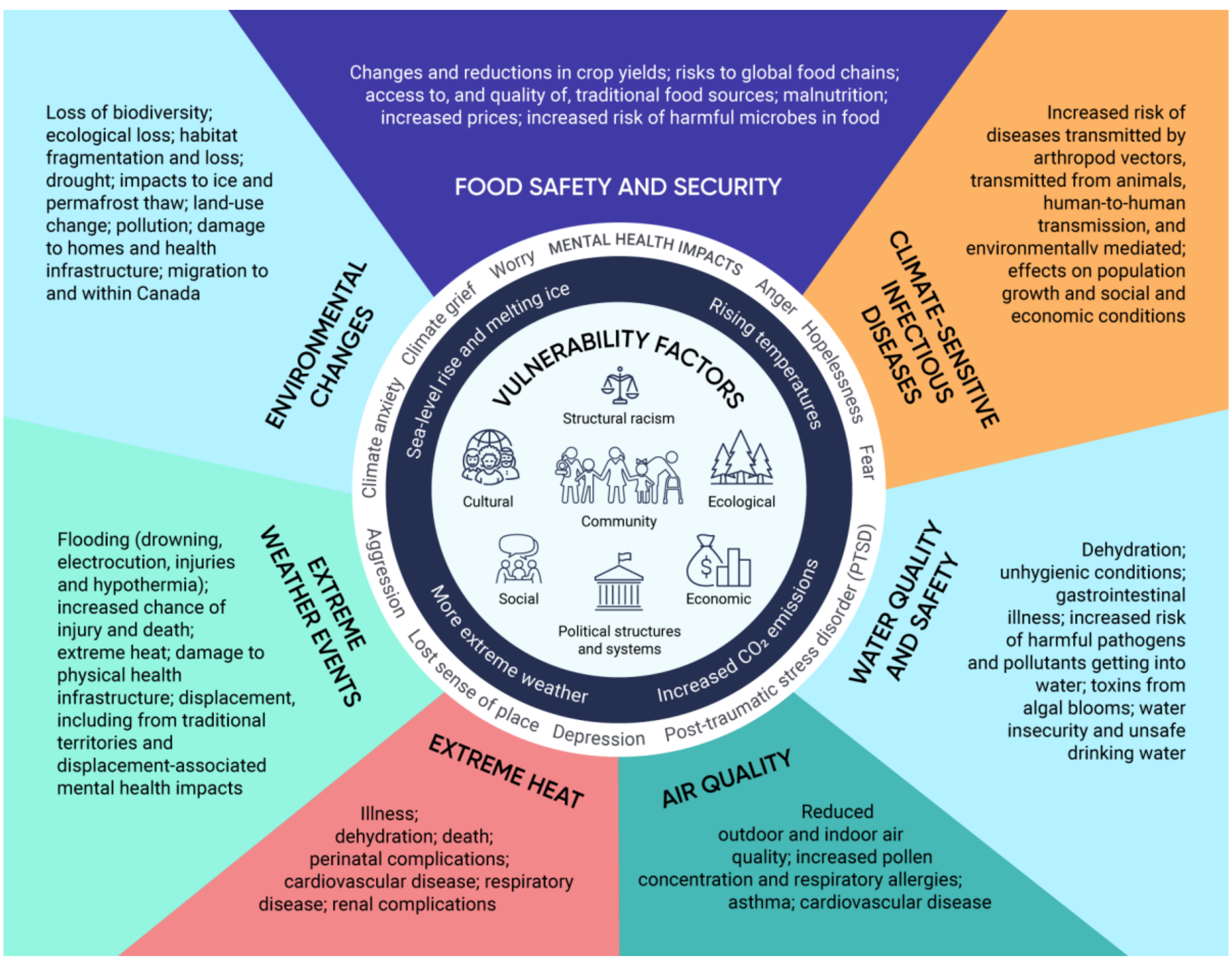


THE RATE OF SEA-LEVEL RISE HAS **DOUBLED** IN THE LAST DECADE

HIGHLY VULNERABLE REGIONS

EXPERIENCE **15X HIGHER MORTALITY RATES** FROM DISASTERS COMPARED TO VERY LOW VULNERABILITY REGIONS (2010-2020)


Reduced ice cover, affecting economic development and Indigenous ways of life
Permafrost degradation, affecting northern infrastructure
Changing animal distributions, affecting food supply
Reduced reliability of ice roads, affecting access to remote mine sites and northern communities
Increased pests (e.g., pine beetle), affecting forest productivity and fire activity
Incidents of drought, affecting forests and agriculture
Sea-level rise and increased coastal erosion, affecting infrastructure and heritage sites
Reduced glacier cover, affecting western water resources and hydropower production
Lower Great Lakes water levels, affecting shipping, hydropower production, and recreation
Increased temperatures, affecting human health due to heat stress and vector-borne diseases


Changes and reductions in crop yields; risks to global food chains; access to, and quality of, traditional food sources; malnutrition; increased prices; increased risk of harmful microbes in food
FOOD SAFETY AND SECURITY
Loss of biodiversity; ecological loss; habitat fragmentation and loss; drought; impacts to ice and permafrost thaw; land-use change; pollution; damage to homes and health infrastructure; migration to and within Canada
ENVIRONMENTAL CHANGES
Increased risk of diseases transmitted by arthropod vectors, transmitted from animals, human-to-human transmission, and environmentally mediated; effects on population growth and social and economic conditions
CLIMATE-SENSITIVE INFECTIOUS DISEASES
MENTAL HEALTH IMPACTS
Worry
Climate grief
Climate anxiety
Anger
Hopelessness
Fear
Aggression
Lost sense of place
Depression
Post-traumatic stress disorder (PTSD)
Sea-level rise and melting ice
Rising temperatures
More extreme weather
Increased CO₂ emissions
VULNERABILITY FACTORS
Structural racism
Cultural
Community
Ecological
Social
Economic
Political structures and systems
Flooding (drowning, electrocution, injuries and hypothermia); increased chance of injury and death; extreme heat; damage to physical health infrastructure; displacement, including from traditional territories and displacement-associated mental health impacts
EXTREME WEATHER EVENTS
Dehydration; unhygienic conditions; gastrointestinal illness; increased risk of harmful pathogens and pollutants getting into water; toxins from algal blooms; water insecurity and unsafe drinking water
WATER QUALITY AND SAFETY
EXTREME HEAT
Illness; dehydration; death; perinatal complications; cardiovascular disease; respiratory disease; renal complications
AIR QUALITY
Reduced outdoor and indoor air quality; increased pollen concentration and respiratory allergies; asthma; cardiovascular disease

WHAT IS CLIMATE SCIENCE LITERACY?

Climate Science Literacy is an understanding of your influence on climate and climate's influence on you and society.

A climate-literate person:

- understands the essential principles of Earth's climate system,
- knows how to assess scientifically credible information about climate,
- communicates about climate and climate change in a meaningful way, and
- is able to make informed and responsible decisions with regard to actions that may affect climate.

WHY DOES CLIMATE SCIENCE LITERACY MATTER?

- During the 20th century, Earth's globally averaged surface temperature rose by approximately 1.08°F (0.6°C). Additional warming of more than 0.25°F (0.14°C) has been measured since 2000. Though the total increase may seem small, it likely represents an extraordinarily rapid rate of change compared to changes in the previous 10,000 years.
- Over the 21st century, climate scientists expect Earth's temperature to continue increasing, very likely more than it did during the 20th century. Two anticipated results are rising global sea level and increasing frequency and intensity of heat waves, droughts, and floods. These changes will affect almost every aspect of human society, including economic prosperity, human and environmental health, and national security.
- Scientific observations and climate model results indicate that human activities are now the primary cause of most of the ongoing increase in Earth's globally averaged surface temperature.
- Climate change will bring economic and environmental challenges as well as opportunities, and citizens who have an understanding of climate science will be better prepared to respond to both.
- Society needs citizens who understand the climate system and know how to apply that knowledge in their careers and in their engagement as active members of their communities.
- Climate change will continue to be a significant element of public discourse. Understanding the essential principles of climate science will enable all people to assess news stories and contribute to their everyday conversations as informed citizens.

CLIMATE SCIENCE LITERACY IS A PART OF SCIENCE LITERACY.

"Science, mathematics, and technology have a profound impact on our individual lives and our culture. They play a role in almost all human endeavors, and they affect how we relate to one another and the world around us. . . . Science Literacy enables us to make sense of real-world phenomena, informs our personal and social decisions, and serves as a foundation for a lifetime of learning."

From the American Association for the Advancement of Science, Atlas of Science Literacy, Volume 2, Project 2061.

People who are climate science literate know that climate science can inform our decisions that improve quality of life. They have a basic understanding of the climate system, including the natural and human-caused factors that affect it. Climate science literate individuals understand how climate observations and records as well as computer modeling contribute to scientific knowledge about climate. They are aware of the fundamental relationship between climate and human life and the many ways in which climate has always played a role in human health. They have the ability to assess the validity of scientific arguments about climate and to use that information to support their decisions.

What is Energy Literacy?

Energy literacy is an understanding of the nature and role of energy in the universe and in our lives. Energy literacy is also the ability to apply this understanding to answer questions and solve problems.

An energy-literate person:

- can trace energy flows and think in terms of energy systems
- knows how much energy he or she uses, for what, and where that energy comes from
- can assess the credibility of information about energy
- can communicate about energy and energy use in meaningful ways
- is able to make informed energy and energy use decisions based on an understanding of impacts and consequences
- continues to learn about energy throughout his or her life

Energy Literacy is a Part of Social and Natural Science Literacy

A comprehensive study of energy must be interdisciplinary. Energy issues cannot be understood and problems cannot be solved by using only a natural science or engineering approach. Energy issues often require an understanding of civics, history, economics, sociology, psychology, and politics in addition to science, math, and technology.

Just as both social and natural science are a part of energy literacy, energy literacy is an essential part of being literate in the social and natural sciences. References to energy can be found in National Education Standards in nearly all academic disciplines.

Why Does Energy Literacy Matter?

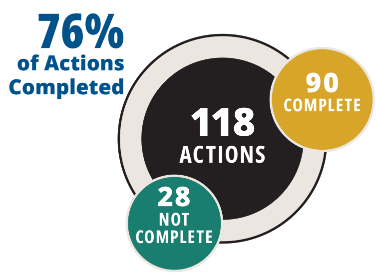
A better understanding of energy can:

- lead to more informed decisions
- improve the security of a nation
- promote economic development
- lead to sustainable energy use
- reduce environmental risks and negative impacts
- help individuals and organizations save money

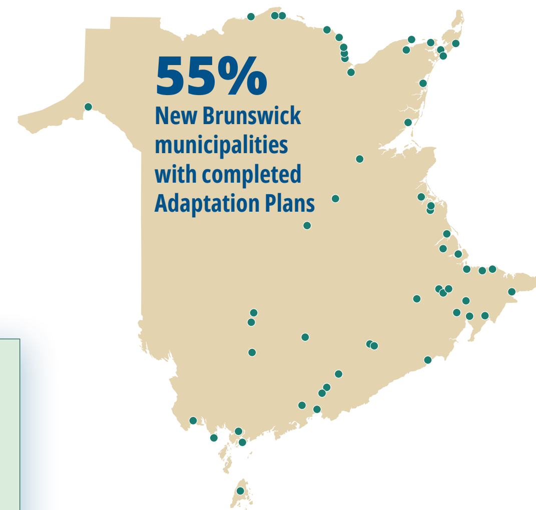
Without a basic understanding of energy, energy sources, generation, use, and conservation strategies, individuals and communities cannot make informed decisions on topics ranging from smart energy use at home and consumer choices to national and international energy policy. Current national and global issues such as the fossil fuel supply and climate change highlight the need for energy education.

New Brunswick's Climate Change Action Plan 2017-2022

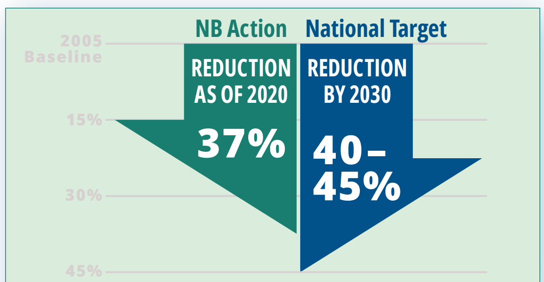
Action Progress and Status



Climate Change Adaptation Plans



New Brunswick GHG Emissions



New Brunswick has reduced emissions by 37% below 2005 levels

Implementation Highlights

- $36M invested from Climate Change fund 2021-2022
- Met and exceeding requirement to serve 40% of in-province electricity sales from renewable sources (51% in 2020-2021).
- Made-in-New Brunswick Output-Based Pricing System.
- Launch of CLIMAtlantic
- Release of updated and expanded NB flood hazard mapping.
- Electric vehicle incentive program
- Over 30,000 homeowners, 2200 businesses, 225 industrial projects registered in 12 energy efficiency programs
- Over $11M invested in climate change initiatives through the Environmental Trust Fund

What We've Seen

- Increase in preparedness to climate change impacts
- Increase in electric vehicle sales
- Increase in energy efficiency programming
- Increase in tools to address climate change and public health risks
- Increase in climate resilient and natural infrastructure
- Increase in climate change education and training resources in schools and workforce
- Increase in energy from renewable sources
- Decrease in overall GHG emissions

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FACT SHEET

Climate Change and Heat Waves

July 2024

Climate change, primarily from the burning of fossil fuels, is causing more frequent and intense heat waves (ClimateData.ca 2024). These heat waves are threatening the safety, well-being, and prosperity of Canadians—even in cities that have historically had more moderate climates, such as Vancouver, Whitehorse, and Halifax.

Globally, 2023 was the hottest year on record, and 2024 is on track to be even hotter (World Meteorological Organization 2024). Canada, which is warming faster than anywhere else on earth, is suffering the consequences of the overheating climate (McBean 2024).

Climate change fuels heat waves

- Canada is warming twice as fast as the global average, and Canada's Arctic is warming nearly four times as fast (Government of Canada 2019; Rantanen et al. 2022).
- Climate change increases the frequency of extreme heat, makes heat waves move more slowly, and results in more frequent and severe heat domes (Seneviratne et al. 2021; Borenstein 2024; Bratu et al. 2022).
- Environment and Climate Change Canada has determined that the June 2024 heat wave that struck central and Eastern Canada was two to 10 times more likely as a result of climate change, with temperatures over 10 degrees higher than normal in parts of Quebec and Atlantic Canada (Shingler 2024).

Climate-fuelled heat makes wildfires worse

- Climate change more than doubled the likelihood of extreme fire weather conditions (high temperatures, low humidity, and drought conditions) in Eastern Canada in 2023, and made Québec's 2023 fire season around 50 per cent more intense (World Weather Attribution 2023).
- Heat waves make it easier for wildfires to start and spread. Intense heat makes lightning, the primary cause of wildfires, more likely to occur (Pérez-Invernón et al. 2023), and makes vegetation drier and more flammable, facilitating the spread of wildfires (Natural Resources Canada 2024).
- During the 2021 heat wave in B.C., the number of active wildfires rose from six to 175, with fires that spread during the heat wave consuming nearly 79,000 hectares, including the entire town of Lytton (White et al. 2023).

- For more information on climate change and wildfires, please see our wildfires fact sheet.

Climate-fuelled extreme heat takes a significant toll on Canadian safety, well-being, and prosperity

- A study in *Nature* found that between 1981 and 2018, 37 per cent of heat-related deaths globally can be attributed to climate change (Vicedo-Cabrera et al. 2021). This increased mortality is evident on every continent.
- Elevated death rates have been documented during and immediately following heat waves in Canada (Government of Canada 2024). The British Columbia heat wave of June 25 to July 2, 2021, saw an estimated 619 heat-related deaths, making it the deadliest disaster in B.C.'s recorded history (BC Coroners Service 2022).
- Climate scientists found that the 2021 B.C. heat wave would have been virtually impossible without human-caused climate change (Philip et al. 2022).
- A 2024 study by the *Institut national de la recherche scientifique* concludes that elevated summer temperatures in Quebec are associated with 470 deaths, 225 hospitalizations, 36,000 emergency room visits, 7,200 ambulance transports, and 15,000 calls to Info-Santé every year (Boudreault et al. 2024).
- Our 2021 report *The Health Costs of Climate Change* projected that the costs of heat-related deaths and reduced quality of life from extreme heat in Canada would range from $3 billion to $3.9 billion per year by mid-century (Clark et al. 2021).
- Our research shows that the 2021 heat wave in B.C. caused $12 million in additional healthcare costs, and that without action on adaptation and health system preparation, the province could average 1,370 heat-related deaths per year by 2030 (Beugin et al. 2023).
- The International Labour Organization finds that 2.4 billion workers, fully 70 per cent of the global workforce, are exposed to extreme heat, with elevated risk of cancer, cardiovascular disease, kidney dysfunction, and physical injury (International Labour Organization 2024).
- Canada's manufacturing sector alone could see annual losses in between $1 billion and $2 billion by 2050, due to the productivity impacts of heat waves on Canada's workforce (Clark et al. 2021).

Governments can act to protect communities and slow further warming

- Scientists have warned that the consequences of climate change will only get worse as the concentration of heat-trapping gases in the atmosphere increases (IPCC 2022). Governments around the world, including Canada's,

must act immediately to reduce greenhouse gas emissions and limit global warming.
- Because the impacts of climate change are already here and getting worse, communities and governments must work together to adapt and prepare for increased fire risks today.
- Ways for governments and other entities to prepare and protect people from extreme heat include:
  - Making buildings safer by encouraging the installation of indoor cooling devices (like heat pumps or air conditioning).
  - Planting green roofs and trees for shade in urban areas—such measures, if implemented in the B.C. Lower Mainland, could reduce heat-related deaths by 12 per cent in the 2030s and cut heat-related hospitalizations by 7 per cent, compared to status quo policies (Beugin et al. 2023).
  - Giving employers and the public up-to-date information on how to keep safe during extreme heat waves.
  - Sending heat warnings out early enough to let people and responders prepare.
  - Designing infrastructure such as roads, railways, and electricity systems to withstand extreme heat and rainfall—this can reduce damage costs by 80 per cent by the end of the century, or up to $3.1 billion each year (Ness et al. 2021).

Proper preparation for heat waves improves health outcomes and makes financial sense

- Proactive adaptation interventions like urban greening and mechanical cooling can reduce the annual cost of heat-related hospitalization by up to 30 per cent in B.C.'s Lower Mainland by mid-century (Beugin et al. 2023).

Resources

- Reporting Extreme Weather and Climate Change: A Guide for Journalists (Clarke and Otto 2024)
- Climate Change and Heatwaves (World Meteorological Organization, 2023)
- Extreme Heat Events Overview (Government of Canada 2024)
- Extreme Heat Preparedness Guide (PreparedBC 2024)
- Health Impacts of Extreme Heat (Climate Atlas of Canada 2024)

Experts available for comment and background information on this topic:

- **Ryan Ness** is Director of Adaptation research at the Canadian Climate Institute and the lead researcher on the Institute's Cost of Climate Change

series. *Ryan est également disponible pour des entretiens en français*. (Eastern Time, English and French).
- **Sarah Miller** is Research Lead in Adaptation at the Canadian Climate Institute (Pacific Time, English).

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FACT SHEET

Climate Change and Wildfires

July 2024

Accelerating climate change, largely from the burning of fossil fuels, makes wildfires bigger, hotter, and more frequent (Climate Atlas of Canada n.d.). With Canada warming twice as fast as the global average (Government of Canada 2019), and home to more than a quarter of the world's boreal forests, the country is experiencing this consequence of global heating firsthand. Canada experienced its most destructive wildfire season ever in 2023, with fires consuming 16.5 million hectares—more than double the previous record and nearly seven times more than the historical average (Natural Resources Canada 2024).

Our research finds that to keep Canadians safe, governments must play both defence and offence—protecting people and ecosystems while accelerating the transition away from fossil fuels to limit further heating (Sawyer et al. 2022).

Climate change makes wildfires worse

- While forest fires are naturally occurring disturbances that contribute to the health and renewal of many forest ecosystems (Canadian Council of Forest Ministers 2019), fires are burning hotter and wilder as the climate warms, causing much greater destruction.
- Wildfire activity is increasingly frequent across Canada (Hanes et al. 2018). The area burned in 2023 was more than six times the historical average (Canadian Interagency Forest Fire Centre 2024).
- Climate change more than doubled the likelihood of extreme fire weather conditions in Eastern Canada in 2023 (World Weather Attribution 2023).
- An overheating climate is making Canadian summers hotter and windier, with more erratic rainfall, including less summer rain in some regions (Bush and Lemmen 2019; Gifford et al. 2022).
- Fire season is starting earlier, is lasting longer, and is harder to contain (Climate Atlas of Canada n.d.; Natural Resources Canada 2024b; Natural Resources Canada 2022). Zombie fires are even beginning to smoulder through the winter (Shingler 2024).
- Lighting strikes become more frequent as the climate warms (McKabe 2023). Ninety-three per cent of the area burned in Canada in 2023 was from fires ignited by lightning; only 7 per cent by human-ignition (Jain et al. 2024).
- Elevated wildfire risk means that, whatever the cause, fires catch, spread, and get out of control much more easily.

Wildfires are damaging people's health and wellbeing

- The smoke from wildfires can spread thousands of kilometres (NASA Earth Observatory 2015), requiring school closures and causing other disruptions while threatening the health of millions of people (Lin 2023), particularly children, seniors, and people with heart or lung disease.
- Hot-burning wildfires release dangerous levels of particulate matter into the air, which is associated with an increased risk of issues like heart disease, cardiovascular disease, lung cancer, and brain cancer (Egyed et al. 2022; Korsiak et al. 2022).
- Heavy smoke takes a significant toll on the Canadian healthcare system. A single week of wildfire smoke in June 2023 was estimated to have cost Ontario over $1.2 billion (Sawyer et al. 2023) in health impacts such as premature deaths, increased hospital visits, and health emergencies.
- Poor air quality from smoke hits the most vulnerable the hardest (Government of Canada, 2022). The impacts of smoke are even more serious for groups like children, seniors, pregnant people, and those who work outdoors.
- Smoke from larger and more frequent wildfires is exacerbating asthma across parts of Western Canada (Matz et al. 2020), and the aftermath of climate-related fires and floods takes a significant toll on mental health (Belleville et al. 2019).
- Wildfires can destroy homes and communities, devastate fragile ecosystems, and threaten economic security. These effects have been linked to post-traumatic stress disorder, depression, anxiety, and suicidal thoughts (Hayes et al. 2022).

Worsening wildfires are making life more expensive

- Wildfires can destroy property, homes, and entire communities, driving up insurance costs and making life more expensive (Gerety 2024; Vaillant 2024).
- The cost of wildfire protection has risen by about $150 million per decade since the 1970s (Government of Canada 2024). These costs exceeded $1 billion for six of the last 10 years.
- The 2016 wildfire in Fort McMurray, Alberta, cost an estimated $9 billion in direct and indirect physical, financial, health, and environmental impacts (Alam et al. 2019). It triggered the largest evacuation in Canadian history, destroying more than 2,400 structures and displacing 85,000 people.
- Wildfires impact key sectors of the economy, including the forest industry, one of Canada's largest employers (Lindsay and Pelai 2024). Wildfires can disrupt forestry operations and reduce the amount of timber available, hurting workers and forest-dependent communities in the process. During the 2017 wildfires in British Columbia, 40 forestry companies were temporarily shut down (Ministry of Environment and Climate Change Strategy 2019).

- The accumulating impacts of global heating, including bigger and more frequent wildfires, are raising the cost of living in Canada from lost jobs, reduced economic activity, and tax hikes to pay for disaster recovery and infrastructure repairs. The additional climate change impacts between 2015 and 2025 alone will cost the average household $700 per year, and will continue to increase moving forward (Sawyer et al. 2022).

Governments can act to protect communities and slow further heating

- Scientists have warned that the consequences of climate change will only get worse as the concentration of heat-trapping gases in the atmosphere increases (IPCC 2022). Governments around the world, including Canada's, must act immediately to reduce greenhouse gas emissions and limit global warming.
- Because the impacts of climate change are already here and getting worse, communities and governments must work together to adapt and prepare for increased fire risks today.
- Federal and provincial governments can promote fire resilience by limiting development in areas at high risk of wildfires, strengthening building codes and regulations (for example, building with fire-resistant materials), and improving forest and vegetation management through prescribed burns and other measures to help reduce fuel available to burn near at-risk communities (Bénichou et al. 2021).
- Alberta and British Columbia's FireSmart programs are examples of initiatives that help communities and individuals reduce their fire risk (FireSmart Alberta 2024; FireSmart B.C. 2024).

Indigenous Peoples are disproportionately impacted, and leading on solutions

- Indigenous communities in Canada have used controlled fire as traditional land management practice since time immemorial. Supporting these cultural burning practices can help reduce the risk of out-of-control wildfires (BC Wildfire Service 2022).
- Eighty per cent of majority-Indigenous communities in Canada are located in fire-prone regions (Asfaw et al. 2019).
- More than 42 per cent of wildfire evacuations have been from majority-Indigenous communities (Webber and Berger 2023).
- Between 1980 and 2021 in Canada, 16 communities (Christianson et al. 2024) were evacuated five or more times, and all but two of those were First Nations reserves.

Resources

- Public Health Risk Profile: Wildfires in Canada (Public Health Agency of Canada 2023)

- The Cost of Wildland Fire Protection (Natural Resources Canada 2024c)
- Flame Wars: Misinformation and Wildfire in Canada's Climate Conversation (Climate Action Against Disinformation 2024)
- Canadian Wildland Fire Information System (2024)
- Forest Fires and Climate Change (Climate Atlas of Canada n.d.)
- Reporting Extreme Weather and Climate Change: A Guide for Journalists (World Weather Attribution 2024)

Experts available for comment and background information on this topic:

- **Ryan Ness** is Director of Adaptation Research at the Canadian Climate Institute and the lead researcher on the Institute's Costs of Climate Change series (Eastern Time, English and French).
- **Sarah Miller** is Research Lead in Adaptation at the Canadian Climate Institute (Pacific Time, English).

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