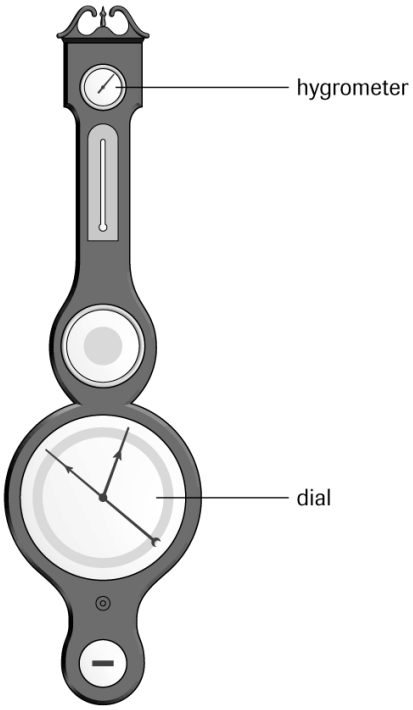
| Date | Person | Description |
|---|---|---|
| 1665 | Robert Hooke | Hooke created the wheel barometer, which had a circular scale and dial assembly to the mercury barometer (**Figure 3**).<br>  <br><br>**Figure 3**: Hooke's wheel barometer |
| 1669 | Robert Boyle | Boyle described the pressure-measuring instrument as a barometer in his plans for a portable barometer. |
| c. 1700 | Gottfried Wilhelm Leibniz | Leibniz described, but never built, an *aneroid* (without liquid) barometer. Pressure changes were detected using a sealed bellows. |
| 1843 | Lucien Vidie | Vidie built the first working version of the aneroid barometer. The aneroid barometer was very portable, and become a common meteorological instrument. |
| Present | | Today, barometers contain sensitive electronic sensors instead of metal aneroid cells. |

# 4.15 EXPLORE AN ISSUE: CANADA AND THE KYOTO PROTOCOL

## Understanding the Issue

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1. Earth's atmosphere is sometimes referred to as a "sink" because it acts as a reservoir for airborne wastes, such as those from industrial activities.
2. (a) Ozone is formed in the stratosphere. UV radiation reacts with oxygen gas to produce oxygen atoms, which are very reactive. The oxygen atoms react with oxygen molecules to form ozone.
   $O_{2(g)} + \text{UV energy} \rightarrow O_{(g)} + O_{(g)}$
   $O_{(g)} + O_{2(g)} \rightarrow O_{3(g)}$
   (b) The ozone in the stratosphere absorbs UV radiation and decomposes back into oxygen molecules and oxygen atoms.
   $O_{3(g)} + \text{UV energy} \rightarrow O_{2(g)} + O_{(g)}$
   (c) Chlorofluorocarbons (CFCs) are relatively inert. Thus, the molecules remain unchanged until they reach the stratosphere. UV radiation causes single chlorine atoms to split off from the CFC molecule. These chlorine

atoms readily react with ozone molecules to create oxygen molecules. The chlorine atoms are regenerated and, therefore, able to continue destroying ozone molecules.

$CCl_3F_{(g)} + \text{UV energy} \rightarrow CCl_2F_{(g)} + Cl_{(g)}$

$Cl_{(g)} + O_{3(g)} \rightarrow ClO_{(g)} + O_{2(g)}$

$ClO_{(g)} + O_{(g)} \rightarrow Cl_{(g)} + O_{2(g)}$

(d) The consequence of ozone depletion in the stratosphere is that "holes," or areas of decreased ozone concentration, are formed. As a result, increased amounts of UV radiation pass through the stratosphere to Earth's surface. Large doses of UV radiation may cause sunburn, cataract formation, and an increased risk of skin cancer.

(e) Student answers will vary. Students may suggest that many factors are responsible for the extended period of time required to eliminate CFCs from asthma inhalers. Chlorofluorocarbons (CFCs) are used commonly in refrigeration units and as propellants in aerosol cans because of the stability of the molecules and their relatively inexpensive production. It is likely that it has taken a relatively long time to find a comparable product that can be safely used in asthma inhalers. It is also likely that it took time for manufacturers to change production equipment to another product.

3. (a) Although posing less harm to the ozone layer, hydrofluorocarbons (HFCs) have not been used as alternative refrigerants since they contribute to the greenhouse effect.

(b) Several hydrocarbons, such as hydrofluoroether (HFE), propane, isobutane, and cyclopentane, are possible alternative refrigerants because they do not react with ozone, they are not significant greenhouse gases, and they are not toxic.

4. The relationship of absorbed solar energy to the amount of energy radiated from Earth's surface is known as an "energy balance." This balance determines the average annual temperature at any location on Earth.

5. (a) A large quantity of energy that re-radiates from Earth's surface is absorbed by greenhouse gases in the troposphere. This trapping of heat energy in the atmosphere is known as the greenhouse effect.

(b) The major greenhouse gases that contribute to the greenhouse effect include atmospheric water vapour, carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$). Other GHGs include ozone ($O_3$), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and hydrofluorocarbons (HFCs).

(c) If the amount of greenhouse gases continues to increase, more heat energy will be trapped in Earth's atmosphere. As a result, a general increase in temperature, or global warming, will likely occur. Global warming may lead to severe weather, such as droughts, severe storms, floods, and tornadoes.

6. The Kyoto Accord proposes to reduce the amount of greenhouse gases in an attempt to slow or stop the rate of global warming and climate change.

## TAKE A STAND: SHOULD CANADA HAVE RATIFIED THE KYOTO PROTOCOL?

The proposition is: "Canada was right to ratify the Kyoto Protocol, a blueprint for greenhouse gas reductions." Students' preparation for the debate will vary depending on the depth of research and resources available, as well as the position taken for the debate. The following answers provide a guideline.

**1. Activities that are responsible for Canada's contribution to global greenhouse gas emissions:**

- Carbon dioxide, $CO_{2(g)}$, is the most significant greenhouse gas released by human activities, mostly through the burning of fossil fuels. It is the main contributor to climate change.
  $6\ O_2 + C_6H_{12}O_6 \rightarrow 6\ H_2O + 6\ CO_2 + \text{energy}$
- Methane, $CH_{4(g)}$, is produced when vegetation is burned, or in livestock farming, rice cultivation, landfills, and coal mining. (Although not applicable to Canada, rice paddies contribute the most methane.)
- Nitrous oxide, $N_2O_{(g)}$, is released when chemical fertilizers and manure are used in agriculture.
- Halocarbons include CFCs (which also damage the ozone layer), and other human-made chemicals that contain chlorine and fluorine. Halocarbons are commonly used as refrigerants and propellants.

**2. Economic forecasts of the costs involved in Canada's participation in Kyoto, in terms of jobs, investment in Canadian business and industry, and taxes:**

- The government of Alberta and the Canadian Chamber of Commerce have predicted a $40 billion cost to meet obligations under the Kyoto Protocol.
- Energy-intensive industries in Ontario and the older smokestack industries may not be able to compete. Some companies will close plants and may reopen in countries that have not ratified Kyoto.
- The Canadian Manufacturers and Exporters Association calculate that 450 000 manufacturing jobs will be lost over the 20-year period covered by Kyoto. The loss of those jobs means a loss in tax revenue, which means that less funds will be available for government services. Other businesses that depend on Canadians' spending may

also fail. The trend could continue in a domino effect. Ontario, as the largest private sector employer, would be the province most affected. However, all provinces would suffer.
- Alberta and the other oil- and gas-producing provinces (British Columbia and Newfoundland) will be hard hit. A carbon tax will affect all Canadians.
- Government analysis predicts that, by 2010, Canada's economy will generate about 1.26 million new jobs, which is about 60 000 fewer than we could expect if Canada had not ratified the Kyoto Protocol. Currently, the Canadian economy is creating new jobs at a rate of about 46 000 per month.
- There will be no direct impact on gasoline prices. Energy efficient houses and cars will reduce overall energy costs.
- The Canadian government predicts that impacts on provincial and territorial economic growth over the next eight years will be marginal and evenly distributed.
- Ontario estimates that, by implementing actions to reduce greenhouse gas emissions, its provincial gross domestic product in the year 2010 will grow by about 0.17%. New jobs would slow by approximately 0.3%, or a delay in creating 18 200 jobs over the next eight years. To put these statistics into context, Ontario's economy created approximately 183 600 jobs over the past year.
- Ontario's manufacturing and automobile industries will benefit from the move to a more energy-efficient society as demand increases for new investments, technology, and equipment to help implement the Canadian climate change plan.
- Production costs of energy and raw materials, such as steel and aluminum, would rise slightly. Investments and activities to reduce greenhouse gas emissions may lead to a slight increase in provincial gross domestic product.
- Actions related to Canada's participation in Kyoto will have significant environmental effects, which will result in reduced health costs.
- In Ontario, the result of participating in the Kyoto Protocol will increase the amount of personal disposable income by 2010 by approximately 0.08%.
- Electricity prices in Ontario could drop by about 0.18 cents/kWh.
- Various Canadian companies are showing leadership in meeting the challenges of climate change.

**3. Evidence that these forecasts may be wrong or at least overly negative:**
- Some scientists oppose global warming science and have signed the Heidelberg Appeal.
- Accu-Weather, the world's leading commercial forecaster, states "Global air temperatures, as measured by land-based weather stations, show an increase of about 0.45°C over the past century. This may be no more than normal climatic variation."
- Information from satellites indicates that there has been a slight cooling in the climate during the last 18 years.
- Some scientists believe that Earth's warming is a result of solar activity.

**4. An action plan proposed by Alberta or another province:**
- Highlights of Alberta's action plan include taking immediate action on climate change, working on partnerships, and making investments to help the province address climate change and to continue to develop a competitive economy.
- Alberta has set a goal to reduce emissions by 20 Mt by 2010.
- Alberta is improving consumer education and developing pilot programs to encourage energy conservation and efficiency.
- Alberta is increasing investment in the development and application of emerging energy technologies. A strong emphasis on renewable energy resources is also a key part of the province's action plan.
- Highlights from Canada's action plan include setting a national goal for Canadians to become efficient consumers and producers of energy in the world and leaders in the development of new, cleaner technologies. The plan involves:
  - setting emissions reductions targets for large industrial emitters;
  - creating an incentive for shifting to lower-emissions technologies and energy sources;
  - establishing a Partnership fund to cost-share emissions reductions with provincial and territorial governments, as well as municipalities, various communities and organizations, and the private sector to increase energy efficiency and reduce emissions;
  - setting up strategic infrastructure investments in innovative climate change proposals, such as urban transit projects, intermodal transportation facilities, and a $CO_2$ pipeline;
  - developing an innovation strategy that encourages innovation and builds on programs, such as Technology Partnerships Canada, the Industrial Research Assistance Program (IRAP), Sustainable Development Technology Canada, and the Technology Early Action Measures (TEAM);
  - achieving climate change goals through such measures as information, incentives, regulations, and tax measures; and
  - taking action in five areas: transportation, housing and commercial/institutional buildings, large industrial emitters, small and medium-sized enterprises, and the international market.

**5. Other related information:**

- Average global temperatures are rising: the 20th century was the warmest the world has seen in 1000 years, and the 1980s and 1990s were the warmest decades on record. A northern country, Canada will feel the impacts of climate change more than most countries.

# 4.16 AIR QUALITY SOLUTIONS—YOUR ROLE

## TRY THIS ACTIVITY: INTERPRETING THE AIR QUALITY INDEX

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**Table 1** Sample Weekly AQI Data

| Pollutant | Mon. conc. (ppb) | Index level | Tues. conc. (ppb) | Index level | Wed. conc. (ppb) | Index level | Thur. conc. (ppb) | Index level | Fri. conc. (ppb) | Index level |
|---|---|---|---|---|---|---|---|---|---|---|
| $SO_2$ | 153 | 24 | 612 | 81 | 288 | 47 | 351 | 56 | 428 | 63 |
| $O_3$ | 52 | 33 | 85 | 53 | 32 | 20 | 60 | 39 | 76 | 50 |
| $NO_2$ | 233 | 38 | 771 | 108 | 460 | 70 | 588 | 85 | 697 | 99 |
| TRS* | 17 | 28 | 56 | 76 | 33 | 53 | 24 | 40 | 46 | 66 |
| CO | 63 | 20 | 428 | 89 | 216 | 59 | 412 | 87 | 366 | 80 |
| $SP^+$ | 12 | 19 | 65 | 79 | 32 | 52 | 40 | 58 | 62 | 77 |

* Total Reduced Sulfur

+ Suspended Particles

**Table 2** Summary of AQI Results

| Day | AQI | Pollutant with highest number |
|---|---|---|
| Monday | 38 | $NO_2$ |
| Tuesday | 108 | $NO_2$ |
| Wednesday | 70 | $NO_2$ |
| Thursday | 87 | CO |
| Friday | 99 | $NO_2$ |

## SECTION 4.16 QUESTIONS

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### Understanding Concepts

1. (a) Primary pollutants are formed from natural and industrial processes, such as burning fossil fuels. Primary air pollutants include carbon dioxide, $CO_{2(g)}$, carbon monoxide, $CO_{(g)}$, sulfur dioxide, $SO_{2(g)}$, methane, $CH_{4(g)}$, nitrogen oxides, $NO_{x(g)}$, particulate matter (PM), and the vapours from volatile organic compounds (VOCs).
   (b) Secondary air pollutants include ground-level ozone and smog, and are formed during chemical reactions between primary pollutants and sunlight or components of air.