

Activity 16 Solutions: Consequences of Chemical Energy

16.1 What is Particulate Pollution?

Your instructor will discuss particulate pollution.

1) Sources of Particulate Pollution

- Light a candle and carefully hold a glass plate above the candle flame. What is the soot that appears on the glass made of? **primarily carbon**
- Your instructor will demonstrate the combustion of various materials. Predict which materials will produce the most and the least particulate pollution.

Which fuel sources produce high levels of soot? Which produce low levels?

	Prediction	Answer
Alcohol	_____	low
Natural Gas	_____	low
Oil	_____	high
Lighter fluid	_____	high
Wax candle	_____	high

- Many filling stations sell gasohol as vehicle fuel. What is gasohol? What advantage does it have over straight gasoline as a vehicle fuel?

Gasohol is gasoline that contains about 10% ethyl alcohol, which is made from corn. Adding ethyl alcohol to gasoline reduces the amount of fossil fuel necessary to power vehicles and reduces the particulate matter produced by them.

- Does an electric glow coil produce soot? **No** Does this mean there is no soot involved with the use of electrical energy? **No** Why or why not?

Hydroelectric and nuclear power plants do not produce soot. Fossil fuel-burning plants do produce soot, but at the point of generation of the electricity, not at the point of its use.

2) Detecting and Removing Particulate Pollution

- Your instructor will demonstrate a laser.

What is a laser beam?

a beam of visible light photons all of the same wavelength and frequency

How can a laser beam detect particulate pollution?

visible light photons reflect off of particles in the air

- b) What is the purpose of an electrostatic precipitator?

it can remove particles from the air

- c) How does the electrostatic precipitator work? Why does it require a high voltage?

The high voltage wires ionize particles in the air, giving them a positive charge. The charged particles are attracted to the negatively charged wire. Particulate pollution is deposited on this wire.

16.2 How Do Combustion Gases Pollute?

3) Complete and Incomplete Combustion

- a) Which carbon-oxygen compound is produced in complete combustion reactions of hydrocarbons, such as the combustion of wood, oil, or gasoline?

carbon dioxide (CO₂)

- b) What is meant by an incomplete combustion reaction?

Any reaction in which the products can further react with oxygen is said to be incomplete.

- c) In incomplete combustion reactions, which carbon-oxygen compound is produced? **carbon monoxide (CO)**

- d) What can be done to correct incomplete combustion?

In industrial settings, complete combustion of hydrocarbons is more likely in an oxygen-rich atmosphere. Furnaces for heating must be properly adjusted to maximize complete combustion and minimize carbon monoxide production.

4) Dangers of Carbon Monoxide

- a) Why is carbon monoxide dangerous to your health?

CO molecules in the blood take away oxygen from the hemoglobin molecules, lowering the oxygen-carrying ability of the blood. At very low parts per million levels, the body is quickly affected by oxygen starvation. High enough levels of carbon monoxide can result in chemical asphyxiation and death.

- b) What are sources of carbon monoxide in a home?

Any source of combustion, such as gas or oil furnaces, kerosene space heaters, or fireplaces can produce dangerous levels of carbon monoxide if these appliances are not properly vented. Carbon monoxide from the exhaust of car motors left running in an attached garage can seep into a home and be fatal. Never run an automobile in a closed garage.

- c) How can carbon monoxide be detected?

Carbon monoxide is a colorless and odorless gas. Furnaces should be checked regularly for carbon monoxide emission. Life-saving carbon monoxide detectors are available and are relatively inexpensive. Some smoke detectors also contain a carbon monoxide detector.

- d) What are the symptoms of carbon monoxide poisoning?

Symptoms of significant concentrations of carbon monoxide include headaches, nausea, and fatigue (flu-like symptoms). At higher concentrations, symptoms include drowsiness, confusion, convulsions, unconsciousness, and even death.

- e) What should you do if you suspect carbon monoxide poisoning?

If you have any symptoms of carbon monoxide poisoning, immediately get out of the house. Anyone who has become drowsy or lost consciousness should be examined by a doctor. The fire department or a heating and cooling expert should check the carbon monoxide levels in your house.

5) Acid Rain

- a) What is acid rain?

Oxides of sulfur in the atmosphere can combine with water to form sulfuric acid. Oxides of nitrogen can combine with water to form nitric acid. When present in the atmosphere, this can make rain acidic.

- b) What is the source of the oxides of sulfur that produce acid rain?

Bituminous or "soft" coal contains more sulfur than anthracitic or "hard" coal. Burning soft coal results in oxides of sulfur (SO_2 and SO_3). One of the primary uses of coal is to produce steam in electric generating plants. Since soft coal is mined in Ohio, it is burned in a number of Ohio power plants.

- c) What is the source of oxides of nitrogen that produce acid rain?

High temperatures and pressures in diesel and gasoline engines, such as those in automobiles, produce oxides of nitrogen.

- d) What damage can be done by acid rain?

Acid rain can damage structures. Acid rain is harmful to living things. Many forms of aquatic life cannot survive in lakes and streams that have become acidic from acid rain. Many plants, particularly fir trees, are damaged and can die from acid rain.

6) Photochemical Smog

- a) What is photochemical smog?

Oxides of nitrogen and hydrocarbons can interact with oxygen in the atmosphere to form smog. These pollutants react photochemically when exposed to ultraviolet and short wave visible radiant energy from the Sun.

- b) What is the primary source of the pollutants that cause smog?

The primary sources of oxides of nitrogen are gasoline and diesel engines.

- c) What harm can smog do?

Smog is harmful to plants and animals. Humans with respiratory problems or other health issues are particularly susceptible to smog.

- d) What can be done to reduce smog?

Catalytic converters on gasoline and diesel engines can remove much of the oxides of nitrogen from the exhaust of vehicles.

7) Inversions

- a) On a sunny day, how does the temperature of air near the ground compare with the temperature of air higher up? Why?

Normally on a sunny day, the air nearer the ground is warmer since the ground is heated by the sun and that heat is then transferred to the air. (More solar energy is absorbed by the ground than by the air.)

- b) What is the cause of convection currents?

Hot air rises because it is less dense than cold air. Cooler air moves downward to replace the hot air that has risen. This causes convection currents in the air.

- c) What role does the motion of convection currents play in the temperature structure of the atmosphere?

As hot air rises, it transfers thermal energy from the ground to the air higher up. As the air rises, it cools (and eventually sinks and is reheated). Thus, the general sunny day temperature structure for the lower atmosphere (troposphere) is that the higher you go, the cooler it is. (Generally the temperature drops 3.6 °F for each 1,000 ft. increase in height.)

- d) What is an inversion?

An inversion results when warm air lies above cooler air, a condition that often happens at night. During an inversion, there is little mixing of the air near the ground and the air in the upper atmosphere.

- e) Why are inversions an important consideration in the study of pollution?

An inversion layer can trap pollution in the inversion layer near the ground because the cooler, more dense, polluted air will not rise above the hotter, less dense air above.

16.3 Depletion of the Ozone Layer

- a) Ozone in the lower atmosphere is produced during the formation of smog. What role does the ozone layer in the higher atmosphere (stratosphere) play?

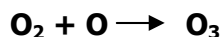
The ozone layer in the stratosphere shields the Earth from ultraviolet photons from the Sun.

- b) How is ozone formed in the upper atmosphere?

In a process called photolysis, an oxygen molecule (O₂) in the upper atmosphere can absorb ultraviolet photons and can split into two atoms of oxygen (O).



An oxygen atom can combine with an oxygen molecule to form a molecule of ozone (O₃).



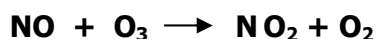
- c) How do ozone molecules absorb ultraviolet radiation?

An ozone molecule can absorb ultraviolet photons and split into an oxygen molecule and an oxygen atom.



- d) In recent decades, large holes in the ozone layer have been detected. How do jet plane engines contribute to the depletion of the ozone layer?

Oxides of nitrogen in the emissions from jet engines can react with ozone to form molecules of oxygen and nitrogen dioxide.



- e) What other class of chemicals can cause depletion of the ozone layer?

Chlorinated fluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) can react with ozone and deplete it. CFCs are used as air conditioner and refrigerator coolants, such as Freon. CFCs have also been used as propellants in aerosol cans.

- f) What danger to human health is associated with the depletion of the ozone layer?

More ultraviolet radiation reaching the Earth's surface would increase our risk of skin cancer.

- g) Group Discussion Question: Is ozone harmful or helpful?

16.4 The Greenhouse Effect and Global Warming

8) The Greenhouse Effect

- a) What form of energy is absorbed by the Earth's surface?

All objects emit electromagnetic radiation with a range of frequencies that is proportional to the temperature of the radiating source. The Sun, with a surface temperature of about 5,800 K, emits energy primarily in the visible light region of the electromagnetic spectrum.

- b) What form of energy is emitted by the Earth's surface?

The Earth, at a temperature of about 300 K, emits radiation primarily in the infrared region of the spectrum.

- c) How does the amount of energy that reaches the Earth compare to the amount of energy that leaves the Earth?

These amounts are (hopefully) the same. If less energy leaves the Earth than is absorbed by the Earth, the temperature of the Earth will increase.

- d) What can block the radiation emitted by the Earth from escaping into space?

Gases in the atmosphere, such as water vapor and carbon dioxide, methane, and CFC's, allow incoming visible light from the Sun to pass through to the Earth. However, these gases absorb infrared radiation leaving the Earth.

- e) What is the Greenhouse Effect?

In the greenhouse effect, carbon dioxide and water vapor molecules in the atmosphere allow incoming visible light to reach the Earth but block outgoing infrared radiation. In addition to the primary greenhouse gases of carbon dioxide and water vapor, CFCs and other gases contribute to the greenhouse effect.

- f) Is the Greenhouse Effect helpful or harmful to life on Earth?

The greenhouse effect is a perfectly natural phenomenon, which keeps the temperature of the Earth's surface comfortably warm. The greenhouse effect of water in the atmosphere on cloudy nights keeps the surface temperature of the Earth warmer than on clear nights. Without the greenhouse effect, surface temperatures would be much colder on average and would fluctuate severely from day to night.

Often the term "greenhouse effect" is used to refer to the "enhanced greenhouse effect" in which human activities lead to unnaturally high concentrations of greenhouse gasses such as carbon dioxide, methane, CFCs, and water vapor. It is believed that such high concentrations of these greenhouse gasses could lead to global warming.

9) **Global Warming**

- a) What could happen to the energy balance of the Earth if the concentration of greenhouse gases in the atmosphere is increased?

If more infrared radiation is trapped by greenhouse gases, the average temperature of the Earth would increase.

- b) Which biological process helps to reduce carbon dioxide in the atmosphere?

Plants remove carbon dioxide from the atmosphere during the process of photosynthesis.

- c) What human activities contribute to the concentration of greenhouse gases?

Combustion of hydrocarbons, such as fossil fuels, increases the concentration of carbon dioxide in the atmosphere. The use of CFCs and HCFs also adds to the concentration of greenhouse gases. Cutting trees and removing plant life decrease the biological systems that are available to convert carbon dioxide into oxygen.

- d) What consequences could result if the average temperature of the Earth increases?

As noted by the OSU researchers Lonny Thompson and Ellen Moseley-Thompson in the video Earth in the Hot Seat, evidence of global warming is already evident in the melting of glaciers. Wide scale of melting of the Earth's ice could raise sea levels and inundate coastal areas. Increasing temperatures could disrupt plant life and precipitation patterns and result in climate changes.

10) **Thermal Pollution**

- a) Electric generating plants heat water into steam to turn turbines. What waste product is emitted by all such heat engines?

thermal energy

- b) Why are most electric generating plants located along large bodies of water?

The waste heat from the plant is dissipated into the water.

- c) What environmental damage can this thermal pollution cause?

damage to aquatic life

11) Group Discussion Question: Fill in the summary of the types of pollution.

Type of pollution	Substances involved	Sources of Pollutants	Effect on environment
Ozone layer depletion	Nitrogen oxide (NO) and CFCs	Jet engine exhaust (NO). Use of CFCs in coolants and aerosols	Depletion of the ozone layer allows more ultraviolet radiation from the Sun to reach the Earth.
Acid rain	Sulfur oxides and nitrogen oxides combine with H ₂ O vapor	Combustion of soft coal (SO ₂). Gasoline and diesel engine exhaust (NO)	Acidic rain is harmful to plant and animal life and damages buildings.
Particulate matter	Soot (carbon)	Incomplete combustion of hydrocarbons (fossil fuels)	Harmful to human health. Can block incoming radiation from the Sun.
Smog	Nitrogen oxides, ultraviolet radiation, and ozone	Gasoline and diesel engine exhaust	Harmful to human health
Global Warming	Greenhouse gases: CO ₂ , CFCs, H ₂ O vapor, and methane	Combustion of fossil fuels, use of CFCs	Increase in avg. temperature of the Earth can result in coastal inundation and disruption of agriculture
Thermal Pollution	Waste thermal energy	Electric generating plants and other industrial plants	Damage to aquatic environment.