



Lesson 2: How Does Ground-Level Ozone Form?

Grade Level: 5-12 | PASS Skills: Process Standard 4/ Standard (1:1, 3, 4), (2:1, 3)

Objectives: Students will be able to diagram the ozone formation process, define VOCs and NO_x, and provide examples of both VOCs and NO_x sources.

Materials: Poster board, art supplies (e.g., markers, colored pencils, etc.), Ozone Formation Poster Rubric (.pdf)

Pre-requisite Knowledge: An understanding that compounds combine through chemical reactions to form other substances is necessary for the comprehension of the material presented in lesson plan 2.

Implementation Tips: The following link (<http://www.epa.gov/airnow/ozone/o3.html>) provides an animation of ozone formation. Use this tool to discuss how ground level ozone is formed through the chemical reaction between VOCs and NO_x. Also, provide the students with a list of the common sources for VOCs and NO_x:

VOCs- gases emitted from:

- Paints
- Cleaning supplies
- Pesticides
- Glues and adhesives

NO_x- gases emitted from:

- Cars
- Refineries
- Power Plants
- Industrial Facilities

***Emphasize that sunlight is the mechanism that allows VOCs and NO_x to chemically combine and form ground-level ozone.**

Activity: To visually conceptualize the ozone formation process and organize the new information learned in lesson 1 and 2, students will create posters using diagrams, definitions, lists/drawings, and summaries.

Notes to Teacher: If supplies are limited, students could be assigned to work in groups. Completed posters can be displayed in the classroom as visual aids to help students remember the new content.

Additional Resources: <http://airnow.gov/index.cfm?action=aqibasics.ozone>

Ozone Formation

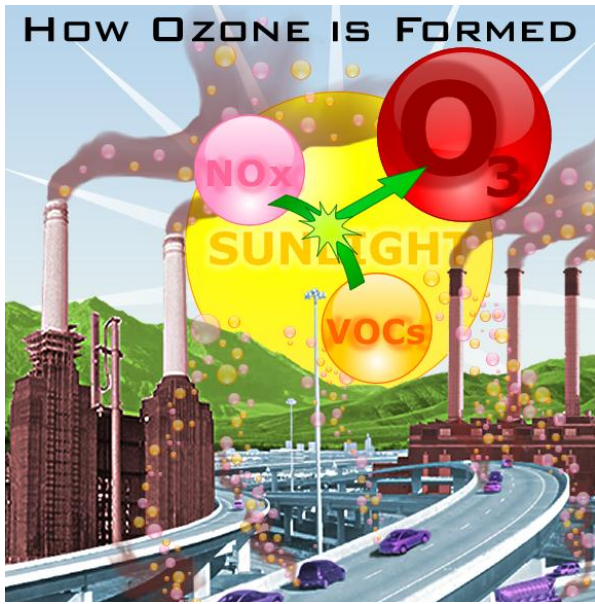
Ground-level ozone is the result of chemical reactions that take place in the presence of sunlight and through the combination of specific man-made and/or natural constituents.

Aside from sunlight (solar radiation), the main ingredients for ground-level ozone formation are volatile organic compounds (VOCs) and nitrogen oxides (NO_x).

VOCs and NO_x

VOCs are a combination of chemicals emitted from both natural and man-made sources. Natural sources include fossil fuel deposits, volcanic emissions, and wildfires. Man-made sources of VOCs include commonly used products like paints, cleaning supplies, pesticides, gasoline vapors, glues and permanent markers.

Nitrogen oxides, on the other hand, are a group of gases made up of nitrogen and oxygen that can combine with other

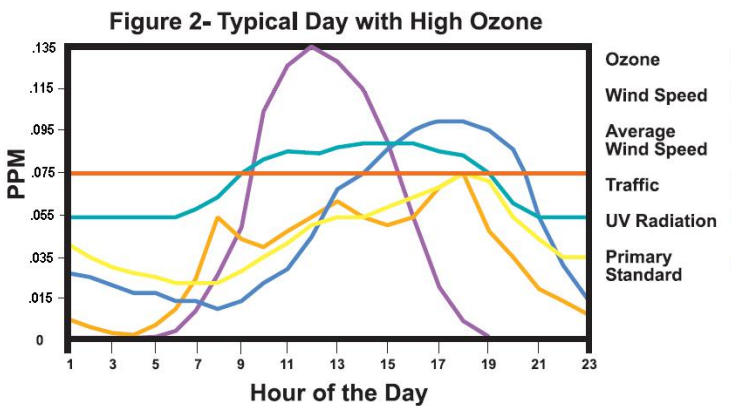


pollutants to form smog. The man-made sources for NO_x include cars, refineries, power plants, and industrial facilities- basically any source that involves the burning of fossil fuels. Natural sources of NO_x emission include lightning, and the burning of biomass.

When exposed to sunlight, VOCs and nitrogen oxides react to form ground-level ozone. As a result, ozone concentrations are typically higher in the summer months when there is plenty of solar radiation to stimulate the reactions. Also, if temperatures are high, the rate of the reactions will increase, thereby elevating ozone concentrations.

The following link on the EPA website provides a great visual demonstration of how this chemical reaction occurs
<http://www.epa.gov/airnow/ozone/o3.html>.

Also, ozone concentrations can fluctuate on a daily basis as well. For example, in the peak of the afternoon between 12 a.m. and 4 p.m. the sun is positioned more overhead, and if there is little or no cloud coverage present, more solar radiation is able to reach the Earth's surface. As a



result, more chemical reactions can occur if there are ample sources of VOCs and NO_x.

Rush-hour traffic in the early morning and evening hours also can increase the precursors of ground-level ozone. Cars on the road release NO_x into the air, which is a catalyst in the ozone formation process. If there is enough sunlight and VOCs during those times, ozone is able to form quite easily.

Activity: *Will require printer or poster paper and art supplies for each student or group (*see accompanying teacher's guide for a downloadable .pdf of the poster project scoring guide).

1. Construct a poster detailing the process of ground-level ozone formation. The following elements could be included on the poster:
 - a. A title
 - b. Caption or paragraph describing "good" ozone and "bad" ozone
 - c. Diagram or drawing of the chemical formation of ozone
 - d. Definitions of VOCs and nitrogen oxides
 - e. List or drawings of VOC and nitrogen oxide sources
 - f. Illustration of daytime changes in ground-level ozone concentrations