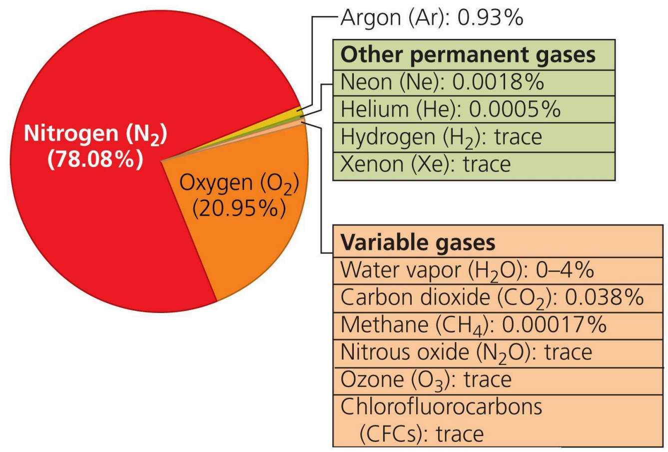
Name ______________________________ Per _____ Date ________________

Air Pollution Notes (Ch. 15)



Primary Pollutants

Polluting compounds that come directly out of the

______________________________, *exhaust pipe, or* ______________________________

source.

**** Primary Pollutant Examples ****

Compound	Formula	Source/Impact
Carbon monoxide		
Lead		
Nitrogen dioxide		
Sulfur dioxide		
Mercury		
Nitric oxide		

Volatile organic compounds (VOCs)		

Secondary Pollutants

Pollutants that have undergone ______________________ in the presence of **sunlight**, **water**, **oxygen**, or other compounds.

Compound	Chemical Equation	Source/Impact
Tropospheric ozone (O_3)		
Sulfuric acid (H_2SO_4)		
Nitric acid (HNO_3)		

Major Air Pollutant: Carbon Oxides

➔ Carbon ______________________________ (CO) is a highly toxic gas that forms during the incomplete combustion of carbon-containing materials.

➔ Carbon ______________________________ (CO_2)

- ________% of carbon dioxide in the troposphere occurs as a result of the carbon cycle. (***cellular respiration***)
- ________% of CO_2 in the troposphere occurs as a result of human activities (mostly burning ________________).

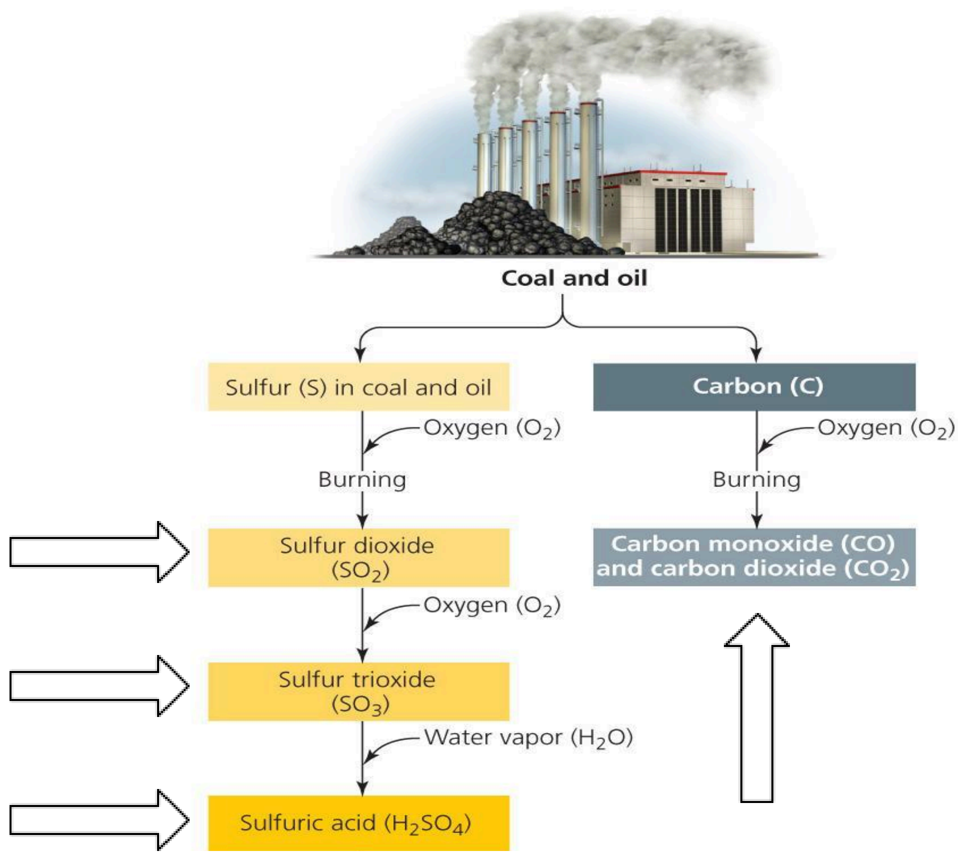
Major Air Pollutants: ______________________ (SO_2) and Sulfuric acid

- About one-third of _____________________________________ in the troposphere occurs naturally through the sulfur cycle.

What are some of the sources of sulfur on Earth?

- Two-thirds of sulfur come from ______________________________________ (anthropogenic), mostly combustion of sulfur-containing coal.

↓↓↓↓↓ The problem with sulfur in the atmosphere ↓↓↓↓↓



Review of Common Ambient Air Pollutants

*Resources @ **crjust.us/7***

Name	Criteria	1° / 2°	Source & Impact	
1. Carbon monoxide (CO)	Yes	1°	Sources:	Incomplete combustion of fuel, combustion of waste.
			Impact:	Out competes O_2 for hemoglobin, potentially suffocating.
2. Lead (Pb)	Yes	1°	Sources:	Exhaust fumes from leaded gasoline, metal smelting.
			Impact:	A heavy metal that is toxic to nerve cells.
3. Nitrogen dioxide (NO_2)	Yes	1° + 2°	Sources:	Transportation (cars, trucks, trains, boats & planes), electrical utilities and some factories. $N_2 + O_2 \rightarrow NO_2$
			Impact:	A component of photochemical smog and acid deposition.
4. Particulate matter (suspended particulate matter / SPM)	Yes	1° + 2°	Sources:	Soot and SO_2 from coal combustion, dust from human activities, natural dust sources
			Impact:	Inhalation causes respiratory diseases, ranging from asthma to respiratory distress and lung cancer
5. Sulfur dioxide (SO_2)	Yes	1°	Sources:	Combustion of coal and petroleum.
			Impact:	Reacts in atmosphere to form SO_3 and H_2SO_4, components of acid deposition. (see reactions sheet)
6. Tropospheric ozone (O_3) (aka: ground level ozone)	Yes	2°	Sources:	Reaction of NO from motor vehicles with sunlight, heat and O_2
			Impact:	Damage to plants and respiratory system, traps heat, and contributes to thermal inversion
7. Carbon dioxide (CO_2)	No	1°	Sources:	Combustion of any organic material. Gasoline, petroleum, coal, natural gas, biomass. Also respiration.
			Impact	A greenhouse gas, CO_2 absorbs thermal radiation and re-emits it at lower wavelengths.
8. Mercury (Hg)	No	1°	Sources:	Combustion of coal.
			Impact:	A heavy metal that is toxic to nerve cells. Capable of bioaccumulation and biomagnification.
9. Nitric Oxide (NO)	No	1°	Sources:	Transportation (cars, trucks, trains, boats & planes). High heat of engine causes $O_2 + N_2 \rightarrow NO$
			Impact:	Poisonous. Reacts with O_2 to form NO_2, leading to ground-level ozone production.
10. Nitric Acid (HNO_3)	No	2°	Source:	Transportation (cars, trucks, trains, boats and planes). $NO_2 + H_20 \rightarrow NO + HNO_3$
			Impact:	Contributes to acid deposition. Harms respiratory system.
11. Peroxacyl nitrates (PANs)	No	2°	Source:	Transportation (cars, trucks, trains, boats and planes). NO_2 + hydrocarbons ("HC") → PANs
			Impact:	A strong respiratory and eye irritant. Potentially mutagenic. Can damage vegetation.
12. Sulfur trioxide (SO_3)	No	2°	Sources:	Combustion of coal and petroleum. Coal has variable quantities of sulfur.
			Impact:	Reacts with water in the atmosphere to form sulfuric acid (H_2SO_4). Contributes to acid deposition.
13. Sulfuric acid (H_2SO_4)	No	2°	Sources:	Combustion of coal and petroleum. Coal has variable quantities of sulfur.
			Impact	Contributes to acid deposition. Harms respiratory system.
14. Volatile Organic Compounds (VOCs)	No	1° + 2°	Sources:	Automobile exhaust, solvents, industrial processes, household chemicals.
			Impact:	Contribute to climate change & ground level O_3. Some are carcinogenic, some harm respiratory system

*Note: The category labeled "1° + 2°" indicates whether the pollutant is a "primary air pollutant", a "secondary air pollutant" or both.

Smog Notes (Ch. 15)

Pre-video question: Go to your Air Pollution notes from the other day. What are the sources and impact of peroxyacyl nitrates (PANs), what is the general chemical equation to produce it, and what type of air pollutant is it (primary or secondary)?

*Watch the video at **crjust.us/smog** and answer the questions:*

1. If the source of the smog in Los Angeles *wasn't* coal-fired power plants, then what was the culprit?
2. What are the usual components found in VOCs and where do they come from?
3. Where do nitrogen oxides come from?
4. What role does UV light play in the formation of smog?
5. PANs and ozone (O_3) are key ingredients in photochemical smog. What are 4 characteristics of urban areas with high levels of photochemical smog?
6. What is temperature inversion?
7. How have regulations impacted emissions and photochemical smog?

Article: In the Fog about Smog: Solving the Smog Puzzle on Earth and from Space
Excerpted from American Chemical Society

Imagine living in Los Angeles in the early 1940s—a fast growing metropolis with endless sunshine, Hollywood celebrities, suburban havens, and fancy cars. Then, imagine waking up one day, and the sun is gone, hidden behind a throat-burning noxious gas. Entire city blocks fade away, blotted out by an unexplainable gas that some thought was part of a World War II attack.

That is exactly what happened in July 1943—and then again and again for more than half a century. Without warning, noxious fog would roll in for days and sometimes weeks, paralyzing the daily activities of Los Angeles residents. Decreased visibility caused fatal collisions of cars and buses; polluted air would spread to the farms beyond the city and damage entire crops in a few hours.

It would take years for scientists to piece together the puzzle of this Los Angeles smog and decades to implement policies to improve the air we all breathe. Today, scientists are able to monitor the pieces of this puzzle from space thanks to NASA's Aura satellite.

But what is smog? What were the pieces that made up this chemical puzzle? And how did Los Angeles free itself from this toxic nuisance and bring back "sunny California"?

Finding the pieces of the smog puzzle

The term "smog" is a contraction of the words "smoke" and "fog." Smog usually consists of soot particles, sulfur dioxide, and other compounds. The citizens of Los Angeles initially blamed the pollution on oil refineries and factories, and they were partly right. State and local officials responded by establishing air pollution control offices, commissioning studies, restricting emissions of sulfur dioxide and smoke from power plants and industry, and banning trash-burning in backyards—a common practice at the time.

While these efforts helped reduce air pollution, they did not reduce the occurrence of smog. In October 1954, a series of intense smog events closed schools and industry in Los Angeles for almost a month. Citizens were frustrated at the lack of progress. They wanted breathable air!

The first piece to the Los Angeles smog puzzle was its smell, which was different from the sulfurous smog that claimed lives in Donora, Pa., and London, England. In those places, the culprit was the burning of coal, but there was very little of that in Los Angeles. Also, something in the Los Angeles smog was destroying rubber tires and damaging crops.

A chemist named Arie "Haagy" Haagen-Smit noticed that the smog in Southern California had a "bleach-like" odor that reminded him of a chemistry lab. In previous research, he used an apparatus to extract flavor compounds from plants to figure out, for instance, what gives pineapples their characteristic smell. Haagy decided to analyze Los Angeles's air with the same apparatus, which indicated the presence of oxidized volatile organic compounds (VOCs). So he exposed smog-sensitive plants to oxidized VOCs. Sure enough, the plants showed damage similar to plants damaged by the Los Angeles smog. Haagy thought he had the answer!

Haagy knew that plenty of VOCs were present in Los Angeles's air, given the significant petroleum industry in Southern California and the number of cars on the road there. Gasoline is made up of organic compounds, some of which evaporate, or volatilize, in the air. (This is why you can smell gasoline fumes.) The petroleum industry in Los Angeles estimated that 120,000 gallons of gasoline were lost every day to evaporation during the refining process. Cars and trucks were equally inefficient, spewing uncombusted or partially combusted gasoline—containing volatile organic compounds—out of their tailpipes at a rate of 850 tons per day.

But when Haagy created synthetic smog in the lab, he unknowingly introduced another piece to the puzzle when oxidizing the VOCs: ozone. Oxidation is the process of combining a molecule with oxygen, and since ozone (O_3) is a highly reactive molecule made of three oxygen atoms, it was the perfect compound to oxidize VOCs for his experiment.

What was oxidizing the VOCs in Los Angeles's air? Surely, it wasn't ozone, a powerful oxidant that was not emitted directly by tailpipes or smokestacks. Haagy and other scientists eventually figured out that nitrogen oxides in the air were reacting with the VOCs, and sunlight provided the catalyst for these chemical reactions to create ozone. Nitrogen oxides are produced during the combustion process inside car engines and are released in the exhaust.

The pieces to the puzzle had fallen into place. Ozone has a bleach-like smell, and it destroys plants and rubber products. Los Angeles had plenty of cars to supply nitrogen oxides and VOCs. And the famous California sunshine was the perfect catalyst for the chemical reactions that form ozone.

One piece of the puzzle was still missing: Why did Los Angeles have more of this kind of smog than other major cities? The answer was a matter of geography and topography. Los Angeles is surrounded by mountains, which trap VOCs and nitrogen oxides in the valleys where people live and breathe. By the early 1940s, Los Angeles had all of the ingredients for catastrophic smog events, which plagued the city for more than half a century.

Taming the culprits of smog

Haagy's findings were published in 1950, and his fellow researchers confirmed in 1955 that ozone from VOCs and nitrogen oxides was at the root of the Los Angeles smog. But when gasoline and cars were identified as the primary pieces of the smog puzzle, researchers pointed a finger at our beloved automobiles, a fundamental part of the American dream.

It took years of politics, policy, and innovation to reduce the emissions of VOCs and nitrogen oxides that make ozone. Enforcement of local laws was difficult because air pollution does not heed city and country borders. Regulations to reduce air pollution quickly became a state, as well as a national, issue and eventually led to the Clean Air Act, passed by Congress in 1970.

While legislators were writing regulations, the petroleum and auto industries were innovating. Oil companies reformulated gasoline to burn more efficiently, reducing the amount of unburned VOCs in car exhaust. Gas stations put sleeves on gas pump nozzles, reducing the amount of VOCs evaporating from gasoline.

Regulations prompted the automobile industry to make more fuel-efficient cars and to develop catalytic converters that reduced the amount of nitrogen oxides and VOCs—along with carbon monoxide—released from cars. Similar technologies, such as selective catalytic reduction devices, were designed to reduce the amount of nitrogen oxides released from power plants.

Steps

1. Read the article, highlight, and provide 10 annotations.
2. Using the information from the article, draw a flowchart for the formation of photochemical smog. Include primary and secondary pollutants, along with sunlight, and any other aspect from the article to make it your own.
3. How have regulations improved air quality?
4. Do some research… What is a catalytic converter and how does it work to decrease air pollution in automobiles and reduce smog?

Smog FRQ *(Excerpt)*

Directions: Use your notes from yesterday and the information from the video and article to write your response. DO NOT use the online scoring guidelines. Complete the FRQ in your notebook.

A. Identify a nitrogen-containing primary pollutant that contributes to the formation of photochemical smog. *(1 pt)*

B. Identify one secondary pollutant that is a component of photochemical smog and describe the following. *(1 pt for identification)*

   i. How the secondary pollutant forms *(1 pt)*

   ii. ONE human health effect of the pollutant *(1 pt)*

   iii. ONE environmental effect of the pollutant *(1 pt)*

C. Earth's natural nitrogen cycle occurs in several steps. Describe one chemical transformation that occurs in the natural nitrogen cycle and discuss the importance of that transformation to an ecosystem. *(2 pts)*

***How many points did you earn?* ______________ pts out of a possible 7 pts**

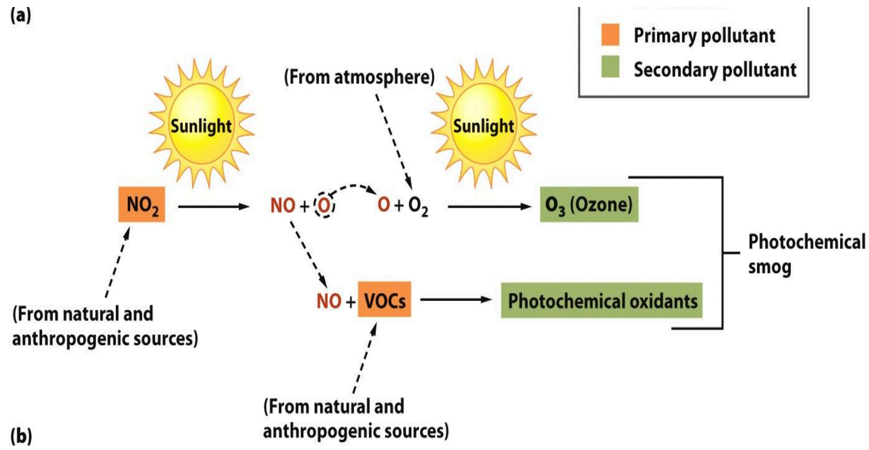
Ozone Notes (Ch. 15)

Photochemical Smog

$$VOCs + NO_x + Sunlight \rightarrow PANs + O_3$$

Thermal Inversions contribute to photochemical smog

- Thermal Inversion - when a relatively ______________________ layer of air at mid-altitude covers a layer of cold, dense air below.
- The warm inversion layer traps ____________________________ that then accumulate beneath it.



Q: How do we decrease photochemical smog?

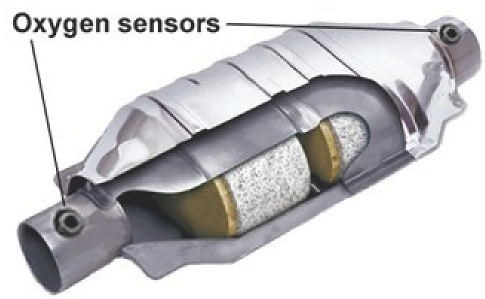
A:

Q: How do you do that?

A:

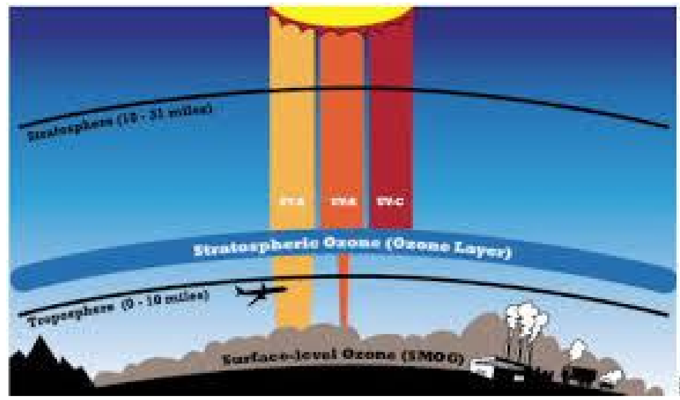
The job of the catalytic converter is to convert harmful air pollutants into less harmful emissions before they ever leave the car's exhaust system. It uses a honeycomb like mesh coated with catalyst metals (____) that will react with the pollutants and produce cleaner gases.

Catalytic converters do this:



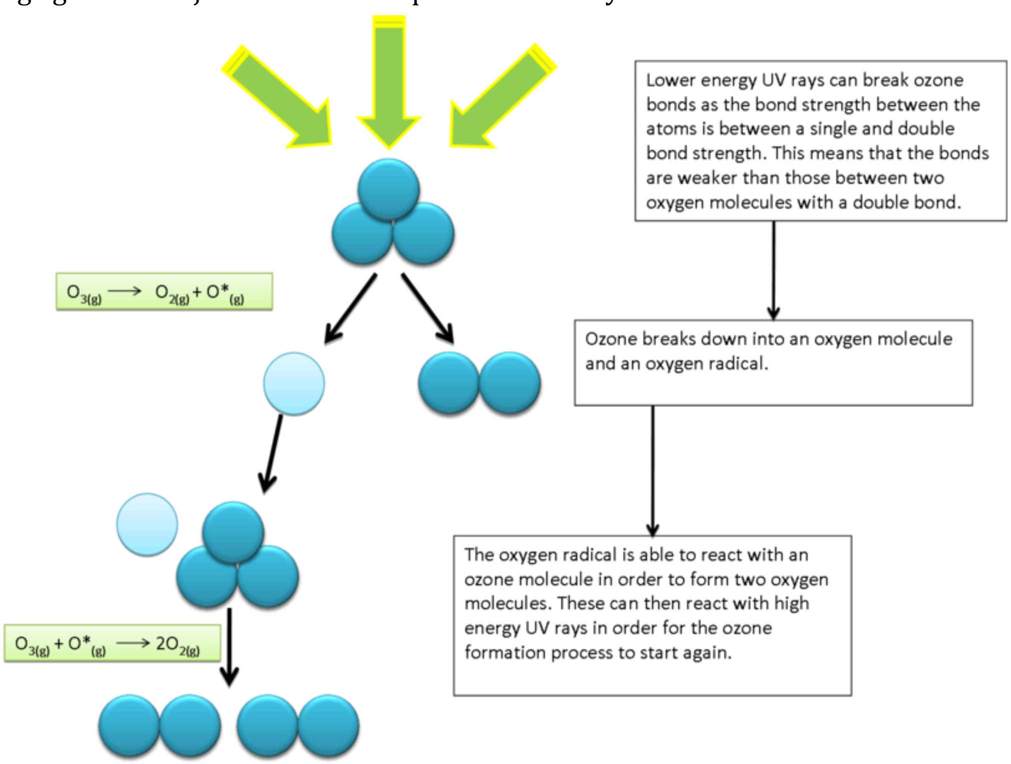
Stratospheric Ozone

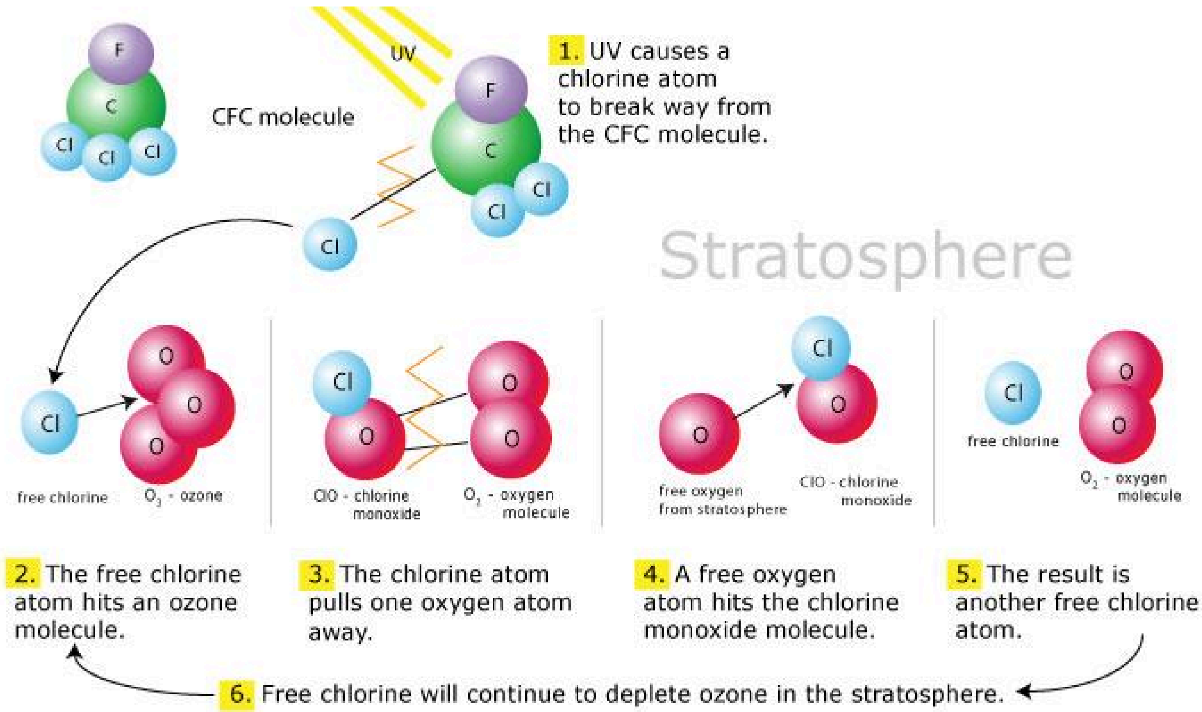
- Concentration of ___________ ppm in stratosphere compared to ___________ ppm in troposphere.
- The stratospheric ozone layer exists roughly 25 kilometers (15 miles) above the Earth.
- Ozone absorbs ______________ % ultraviolet radiation from the sun, which can cause skin cancers.
- Extra UV-B radiation reaching Earth also inhibits the reproductive cycle of _________________________________, single-celled organisms such as algae that make up the bottom rung of the food chain.



Anthropogenic Contributions to Ozone Destruction

- Certain chemicals can break down ozone, particularly ______________________________.
- The major source of chlorine in the stratosphere is a compound known as chlorofluorocarbons (________________)
- CFCs are used in refrigeration and air conditioning, as propellants in aerosol cans and as "blowing agents" to inject air into foam products like Styrofoam.





More Effects of Ozone Depletion

- ➔ Eye cataracts
- ➔ Sunburn and cancer
- ➔ Weaker immune systems
- ➔ Interference with photosynthesis which leads to lower crop yields as growth is reduced
- ➔ Plants suffer as they become more susceptible to disease
- ➔ Plankton near the surface dies which disrupts food chains

From National Geographic:

> *One atom of chlorine can destroy more than a hundred thousand ozone molecules, according to the the U.S. Environmental Protection Agency.*
>
> *The ozone layer above the Antarctic has been particularly impacted by pollution since the mid-1980s. This region's low temperatures speed up the conversion of CFCs to chlorine. In the southern spring and summer, when the sun shines for long periods of the day, chlorine reacts with ultraviolet rays, destroying ozone on a massive scale, up to 65 percent. This is what some people erroneously refer to as the "ozone hole." In other regions, the ozone layer has deteriorated by about 20 percent.*
>
> *About 90 percent of CFCs currently in the atmosphere were emitted by industrialized countries in the Northern Hemisphere, including the United States and Europe. These countries banned CFCs by 1996, and the amount of chlorine in the atmosphere is falling now. Scientists had estimated it would take another 50 years for chlorine levels to return to their natural levels. In*

fact, in November 2018, the UN released a report saying that, based on the latest science, the ozone layer is on track to be fully healed within 50 years.

Write down a few interesting facts from the video at ***crjust.us/o3***

Homework Due Tuesday, April 2, 2019

Directions: Read about indoor air pollution on pages 427-430 in our textbook (take pictures of the pages with your phone, if you'd like). Answer the questions:

1. What are the main source of indoor air pollution in developing countries?

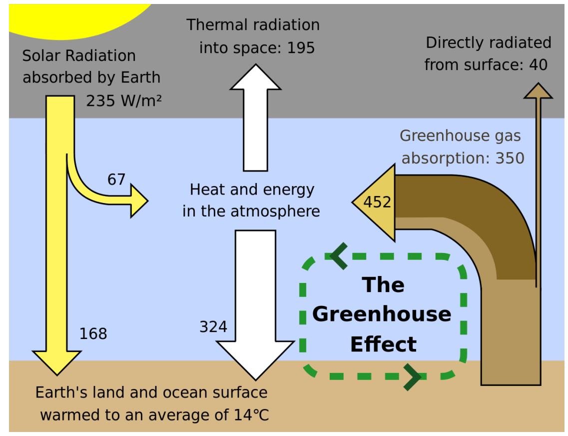
2. What's the problem with asbestos?

3. What is the problem with radon-222 and how do you mitigate the issue in your own home?

4. What are examples of household VOCs?

5. What is sick building syndrome?

The Greenhouse Effect Notes (Ch. 19)



Energy from the Sun that makes its way to Earth can have trouble finding its way back out to space. The greenhouse effect causes some of this energy to be absorbed and released by greenhouse gases.

Without the greenhouse effect, Earth's temperature would be below freezing. It is, in part, a natural process. However, Earth's greenhouse effect is getting stronger as we add greenhouse gases to the atmosphere.

How Does It Work? - UV radiation from the sun is absorbed at Earth's surface then radiated back into the atmosphere as infrared heat. As the heat makes its way through the atmosphere and back out to space, greenhouse gases absorb much of it. Why do greenhouse gases absorb heat? Greenhouse gases are more complex than other gas molecules in the atmosphere, with a structure that can absorb heat. They radiate the heat back to the Earth's surface, to another greenhouse gas molecule, or out to space.

Greenhouse Gases - There are several different types of greenhouse gases. The major ones are carbon dioxide, water vapor, methane, nitrous oxide, CFCs, and tropospheric ozone. These gas molecules all are made of three or more atoms. The atoms are held together loosely enough that they vibrate when they absorb heat. Eventually, the vibrating molecules release the radiation, which will likely be absorbed by another greenhouse gas molecule. This process keeps heat near the Earth's surface, where the majority of greenhouse gases are also located.

Most of the gas in the atmosphere is nitrogen and oxygen – both of which are molecules made of two atoms. The atoms in these molecules are bound together tightly and unable to vibrate as much, so they cannot absorb heat and contribute to the greenhouse effect.

Use the textbook and **climate.nasa.gov/causes** to fill out the table of greenhouse gases below:

Greenhouse Gas	Source/Notes	Conc. in Troposphere
Water vapor (H_2O)	The most abundant greenhouse gas, but importantly, it acts as a feedback to the climate. Water vapor increases as the Earth's atmosphere warms, but so does the possibility of clouds and precipitation, making these some of the most important feedback mechanisms to the greenhouse effect.	Variable w/ temperature *(increased temps mean more water vapor)*
Carbon dioxide (CO_2)		411 ppm (as of February '19)

Methane (CH_4)		1867 ppb (as of January ‘18)
Nitrous oxide (N_2O)		332 ppb (as of January ‘19)
Chlorofluorocarbons (CFCs)		232 ppt (as of 2013)

On Earth, human activities are changing the natural greenhouse. Over the last century the burning of fossil fuels like coal and oil has increased the concentration of atmospheric carbon dioxide (CO_2). This happens because the coal or oil burning process combines carbon with oxygen in the air to make CO_2. To a lesser extent, the clearing of land for agriculture, industry, and other human activities has increased concentrations of greenhouse gases.

The consequences of changing the natural atmospheric greenhouse are difficult to predict, but certain effects seem likely:

- ➔ On average, Earth will become warmer. Some regions may welcome warmer temperatures, but others may not.
- ➔ Warmer conditions will probably lead to more evaporation and precipitation overall, but individual regions will vary, some becoming wetter and others dryer.
- ➔ A stronger greenhouse effect will warm the oceans and partially melt glaciers and other ice, increasing sea level. Ocean water also will expand if it warms, contributing further to sea level rise.
- ➔ Meanwhile, some crops and other plants may respond favorably to increased atmospheric CO_2, growing more vigorously and using water more efficiently. At the same time, higher temperatures and shifting climate patterns may change the areas where crops grow best and affect the makeup of natural plant communities.

Homework: Complete the Vee Map for the Greenhouse Effect Investigation by tomorrow.

Knowing

Focus Questions

In this investigation, we will place a thermometer in a plastic bottle to simulate the greenhouse effect. The plastic bottle is a model of Earth's atmosphere and the investigation we are exploring is:

What effect does enclosing a thermometer in a model of our atmosphere have on temperature?

Word List

- *Greenhouse effect*
- *Temperature*
- *Light*
- *Reflect*
- *Absorb*
- *Greenhouse gases*
- *Atmosphere*
- *Infrared radiation*
- *UV radiation*
- *Earth*

Concept Map (draw on back)

Prediction/Hypothesis

Procedures

Doing

Analysis and Claims

Need more room? Answer on the back!

1. *Write a claim that answers the question you are investigating. Reference your data in your claim.*
2. *Draw an image of your lab setup. Label the control and experimental groups. Reference the independent and dependent variables.*
3. *We used a model to simulate the greenhouse effect. What did the bottle represent?*
4. *What did the construction paper on the bottle demonstrate?*
5. *How did this experiment show you the greenhouse effect?*

Data (graphs, tables, charts, etc.)

Concept Map - *Use the words from the front and explain the greenhouse effect in your concept map. You may use the words more than once if you need to.*

Lab Setup

Answers - *Analysis & Claims*

Global Climate Change Notes

Directions: This set of notes corresponds to a "Pear Deck" slideshow. You will be able to follow along on your Chromebook screen. Because I would like all of us to stay together, please be don't work ahead.

Head over to **climate.nasa.gov/images-of-change** and look at recent evidence of global climate change. Choose three examples and briefly discuss the impacts of global climate change.
1.
2.
3.

Global Change

- ➔ Sea level rising
- ➔ Altered biogeochemical cycles
- ➔ Decreased biodiversity
- ➔ Global climate change

Global Climate Change

- ➔ Increased storm intensity
- ➔ Altered patterns of precipitation and temperature
- ➔ Global warming

Global Warming

- ➔ Warming of the planet's land, air, and water
- ➔ Increased heat waves
- ➔ Reduced cold spells

"Scientific evidence for warming of the climate system is unequivocal."

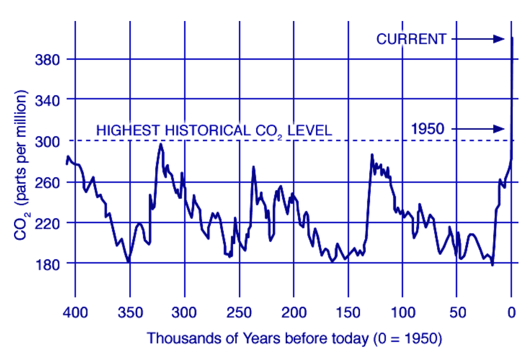
-Intergovernmental Panel on Climate Change (IPCC)

What do you think the word "intergovernmental" means? What is the IPCC?

Tropospheric carbon dioxide concentrations from 400,000 years ago to today

The graph shows CO_2 levels during the last three glacial cycles, as reconstructed from ice cores.

During ice ages, CO_2 levels were around 200 parts per million (ppm), and during the warmer interglacial periods, they hovered around 280 ppm (see fluctuations in the graph). In 2013, CO_2 levels surpassed 400 ppm for the first time in recorded history. This recent relentless rise in CO_2 shows a remarkably constant relationship with fossil-fuel burning, and can be well accounted for based on the simple premise that about 60 percent of fossil-fuel emissions stay in the air.



- ➔ What's the difference between direct and proxy measurements?

- ➔ In which way are proxy measurements made of CO_2 concentrations and temperatures?

What "story" does the graph tell about carbon dioxide concentrations over time?

_________________: Concentration of tropospheric carbon dioxide emissions, as of February 2019.

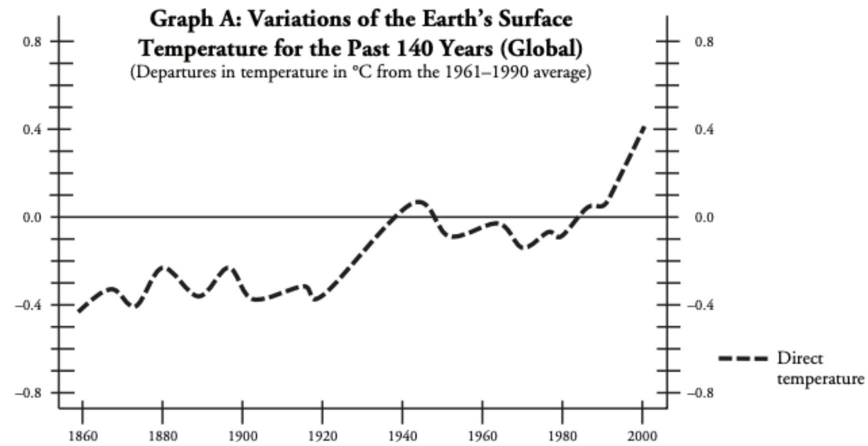
The tropospheric CO_2 concentration in February 2009 was 386 ppm. What is the percent increase of CO_2 from February 2009 to 2019? Show your work →

(Hint: Percent change can be calculated as the absolute value of the difference between the original and new numbers, divided by the original number. Multiply by 100 to move the decimal point two to the right. Don't forget to tack on a percent sign!)

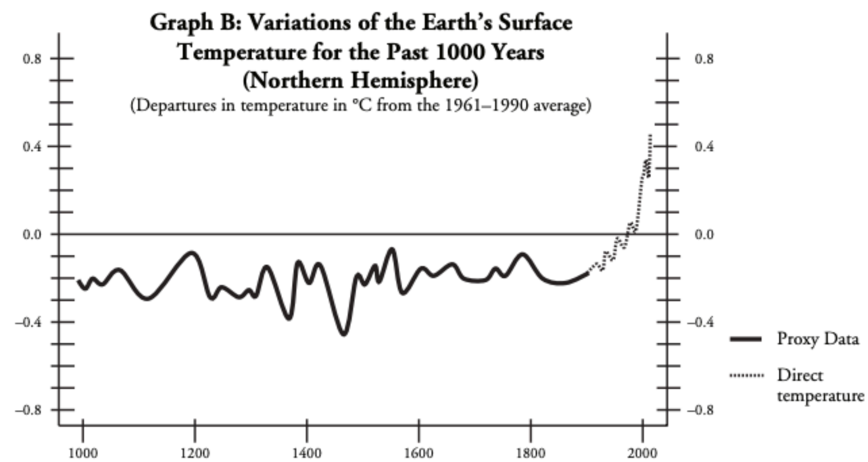
CO_2 is a greenhouse gas. What are a few others?	Explain what greenhouse gases do in the troposphere. Look at your notes from yesterday if you need to!

Evidence of Global Climate Change: Earth's Surface Temperatures

1. The horizontal line at zero represents a baseline average temperature. From what years is this baseline temperature calculated in Graphs A and B?



2. When a data point is plotted below the horizontal line on either graph A or graph B, what does that indicate about the Earth's average temperature that year?



3. What does the trend show in graph A? Explain your answer fully, citing specific information from the graph, including comparisons to the horizontal line at zero.

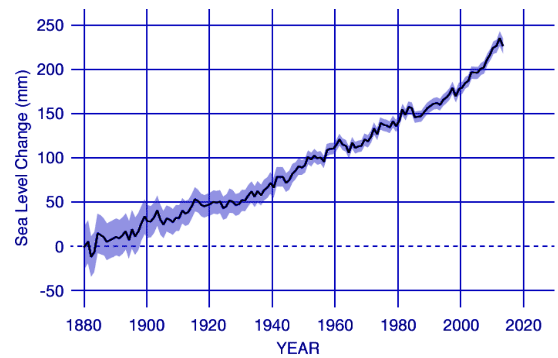
4. Compare the average annual temperature over the past 1000 years with the average annual temperature in the past 30 years.

Evidence of Global Climate Change: Sea Level Rise

➔ What are two reasons sea levels will rise?

Calculate the rate the sea level has risen from 1880 to 2013.

(Hint: You can easily calculate a rate on any x,y graph by calculating the slope of the line. Remember, slope is calculated rise over run. Don't forget units!)

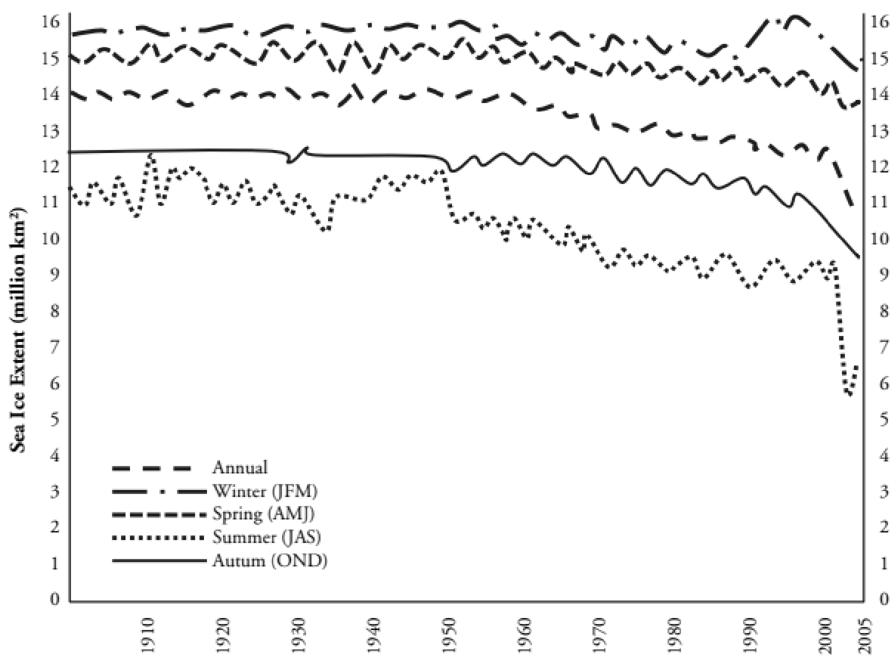


Evidence of Global Climate Change: Arctic Sea Ice <u>Extent</u> ← *define*

1. What is the dependent variable in the graph and what are its units?

2. What area of the Earth is represented by the data?

3. Using a complete sentence, describe the trend for the **annual** sea ice area over the last 100 years?



4. Using your knowledge from the Earth's surface temperatures graph earlier in the lesson, propose an explanation for the change in annual sea ice area.

5. The glaciers and ice caps on the Earth help to reflect the Sun's energy back into space. This is called the ice's **albedo**, and reflective items on Earth have a high albedo. How might the change in sea ice and its reduced albedo affect the Earth's temperature?

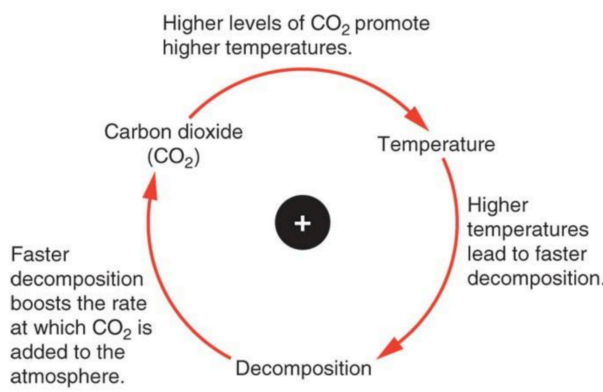
Consequences — Global Climate Change Notes

Watch the video on thawing permafrost at **crjust.us/permafrost** and take notes on what permafrost is and why its thawing accelerates climate change…

Feedback Loops—*The global greenhouse system is made up of several interconnected subsystems with many potential positive and negative feedbacks.* ***Positive feedback*** *amplifies changes and makes them more pronounced while* ***negative feedback*** *dampens changes in an effort to return to a normal state.*

Using everyday language, describe the complex feedback systems detailed above. Be descriptive!

Positive Feedback Example—



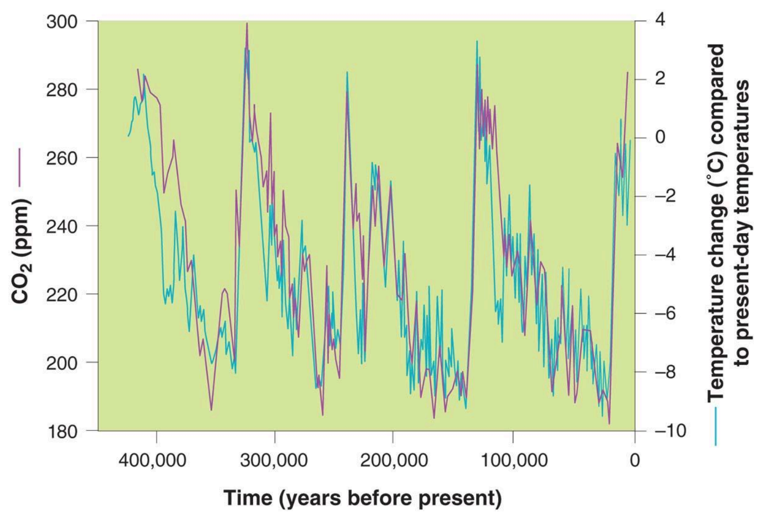
More Feedback Examples

1. **Ocean as Carbon Sink** — The ocean is the largest carbon sink on Earth. Carbon dioxide can dissolve into the ocean at its surface, but water temperature plays a role in how much gas can dissolve into it. Cooler waters allow more dissolved gas and warmer waters allow less. As the ocean warms due to global warming, it may release more of the dissolved CO_2 into the atmosphere. Since CO_2 is a greenhouse gas and can enhance the greenhouse effect, global temperatures will rise in response.

2. **Thawing Permafrost**— As atmospheric concentrations of CO2 from anthropogenic sources increase, the Arctic regions become substantially warmer and the frozen tundra begins to thaw. As it thaws, the tundra develops areas of standing water with little oxygen available under the water as the thick organic layers of the tundra begin to decompose. As a result, the organic material experiences anaerobic decomposition that produces methane, a stronger greenhouse gas than CO2, which should lead to even more global warming.

Practice & Homework

Directions: Complete all parts of the assignment by the start of our next class! Do the work in your notebook.



1. The graph at right has two y-axes, one for atmospheric CO_2 emissions and one for global temperature changes. The x-axis is time in years. Explain how CO_2 concentrations and global temperatures are two factors that vary together.
2. There is a common misconception that the stratospheric ozone layer plays a role in global warming. This misconception likely comes from the fact tropospheric ozone is a greenhouse gas. Explain what stratospheric ozone and tropospheric ozone do. HINT: Find this information on two other notes packets from the Air Pollution Unit.
3. There are examples of negative feedback in climate systems, too. Do a little research to find an example of negative climate feedback. Explain the process and draw a schematic of the system.
4. Read pages 540-542 in our textbook (**crjust.us/pp540542**). Answer these questions:
    a. What is the Kyoto Protocol and explain its significance in global climate change.
    b. Carbon sequestration is heralded as one potential solution to global climate change. How is carbon sequestered? Google one of the examples from the textbook and explain how it works.
    c. How does the Kyoto Protocol affect both developing and developed countries?

Air Quality Solutions

- ➔ Available here due to formatting: https://docs.google.com/document/d/1ZcI4cgwzOwPiqs309EdRBTS5hebVPQACigZj0wDWToA/edit?usp=sharing