

Power Plant CO₂ Pollution

Description: Surface area-to-volume activity that shows how surface areas and volumes even in small amounts can add up to a lot. This lesson uses power plant particulate pollution to show how much even 1% adds up to in one year. This lesson utilizes a spherical model for the particles.

Level: High school geometry and up.

Discipline: Mathematics, Chemistry

Materials Needed: Calculator, pencil, and this paper.

Take Away: Students will learn that particulate pollution even in small amounts when proper controls are used can add up to a lot of volume on the global scale. They will also use the ideal gas law to review what they have previously used in chemistry.

Background information:

The state of Wyoming produces 6,168 megawatts (MW) of electricity per year from coal fired power plants. Power generation from coal creates a large amount of pollution in the form of CO₂ that causes global warming. Current technology can remove around 30-50% of the CO₂ a coal fired power plant produces. However, 50-70% still remains and this is still a lot of pollution as you will see.

An example we will use is the Laramie River Power Station that is located in Wheatland Wyoming. This plant alone produces 1,710 MW of electricity and emits 15,248,626 tons of CO₂ pollution per year into the atmosphere when technology is not employed to reduce this.

Concepts: Pollution, technology, Nano particles, metric system, unit conversions, chemistry, algebra, and geometry concepts

Vocabulary:

1 Nanometer = 1×10^{-9} meter

Nanoparticle: a particle between 1-100nm

Coal Fired Power Plant: where electricity is produced from the combustion of coal

Lesson:

The state of Wyoming produces 6,168 megawatts (MW) of electricity per year from coal fired power plants. Power generation from coal creates a large amount of pollution in the form of CO₂ that causes global warming. Current technology can remove around 30-50% of the CO₂ a coal fired power plant produces. However, 50-70% still remains and this is still a lot of pollution as you will see.

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Part A:

If technology is used that can remove 30% of CO₂; how, much CO₂ does the Laramie River Power Station still put into the atmosphere every year? Your answer should be in $\frac{\text{tons}}{\text{yr}}$.

$$15248626 \frac{\text{tons}}{\text{yr}} \times 70\% = 10,674,038 \frac{\text{tons}}{\text{yr}}$$

Of CO₂ is still emitted after using the best technology available.

Part B:

Using the Laramie River Power Station example, determine how many $\frac{\text{tons}}{\text{yr}}$ of CO₂ are released per MW? Your answer will have units of $\frac{\text{ton/yr}}{\text{MW}}$.

$$\frac{10674038 \frac{\text{tons}}{\text{yr}}}{1710 \text{ MW}} = 6242 \frac{\text{tons/yr}}{\text{MW}}$$

Part C:

Using your answer from Part B, calculate the total amount of CO₂ released in Wyoming for all of the power plants combined in $\frac{\text{ton}}{\text{yr}}$.

$$6,168 \text{ MW} \times 6242 \frac{\text{tons/yr}}{\text{MW}} = 38,501,445.5 \frac{\text{tons}}{\text{yr}} \text{ released}$$

Part D:

You determined how much mass this was in Part C. Now determine how much CO₂ is produced in Wyoming per year by volume. You will need to use the Ideal Gas equation from chemistry to do this:

Ideal Gas Equation

$$PV=nRT$$

Given:

$$T = 60\text{ }^{\circ}\text{C}$$

$$P = 1\text{ atm} = 101.325\text{ kPa}$$

$$R = 8.314 \frac{\text{kPa m}^3}{\text{kmol K}}$$

$$1\text{ lb} = 454\text{ g}$$

$$2000\text{ lb} = 1\text{ ton}$$

$$273.15\text{ }^{\circ}\text{C} = \text{K}$$

D.1: Determine mass of CO₂ in lb/mol using molecular weights:

Molecular Weight of Carbon: 12 g/mol

Molecular Weight of Oxygen: 16 g/mol

$$\text{CO}_2 = 12 + 2(16) = 44\text{ g/mol}$$

$$= 44 \frac{\text{g}}{\text{mol}} \times \frac{1\text{ lb}}{454\text{ g}} = 0.097\text{ lb/mol}$$

D.2: Using your answer from Part C, find the number of moles (n) of CO₂ released per year in Wyoming. Final answer needs to be in kmols.

$$n = 38501445 \frac{\text{ton}}{\text{yr}} \times \frac{2000\text{ lb}}{1\text{ ton}} \times \frac{1\text{ mol}}{0.097\text{ lb}} \times \frac{1\text{ kmol}}{1000\text{ mol}}$$
$$= 793,844,227 \frac{\text{kmol}}{\text{yr}}$$

D.3: Using your answer from Part D.2, find the volume (V) of CO₂ released per year in Wyoming. The final answer needs to be in m³/yr.

$$V = \frac{nRT}{P}$$

$$V = \frac{793844227 \frac{\text{kmol}}{\text{yr}} \times 8.31447 \frac{\text{kPa m}^3}{\text{kmol K}} \times 333.15\text{ K}}{101.325\text{ kPa}}$$

$$V = 21,701,665,575.7 \frac{\text{m}^3}{\text{yr}}$$

Part E:

A Goodyear blimp has a volume of 5740 m^3 . To put this in perspective, determine how many Goodyear blimps worth of CO_2 are emitted by Wyoming each year.

$$\frac{21,701,665,575.7 \frac{\text{m}^3}{\text{yr}}}{5740 \frac{\text{m}^3}{\text{blimp}}} = 3,780,778 \frac{\text{blimps}}{\text{yr}}$$

STOP!!!

Part F:

Now that we have a grasp on how much volume of CO_2 is emitted every year, you can see why it is important to decrease the output of it. Nanotechnology can be used with catalysts to increase the amount of surface area available for reactions to occur. Let's calculate their individual surface area and volume to compare the large difference in surface areas between micro catalysts and Nano catalysts. The micro catalysts have an average radius of $50 \mu\text{m}$, or $5 \times 10^{-5} \text{ m}$. The surface area of a sphere is $4\pi r^2$ and the volume is $\frac{4}{3}\pi r^3$

$$SA = 4 \times \pi \times (5 \times 10^{-5} \text{ m})^2 = 3.142 \times 10^{-8} \text{ m}^2 \text{ or } 3.142 \times 10^4 \mu\text{m}^2$$

$$V = \frac{4}{3} \times \pi \times (5 \times 10^{-5} \text{ m})^3 = 5.236 \times 10^{-13} \text{ m}^3 \text{ or } 5.236 \times 10^5 \mu\text{m}^3$$

Part G:

Repeat F except now use an average radius of 50 nm , or $5 \times 10^{-8} \text{ m}$.

$$SA = 4 \times \pi \times (5 \times 10^{-8} \text{ m})^2 = 3.142 \times 10^{-14} \text{ m}^2 \text{ or } 3.142 \times 10^4 \text{ nm}^2$$

$$V = \frac{4}{3} \times \pi \times (5 \times 10^{-8} \text{ m})^3 = 5.236 \times 10^{-22} \text{ m}^3 \text{ or } 5.236 \times 10^5 \text{ nm}^3$$

Part H:

A very important property of Nano particles is there very high surface area to volume ratio. To demonstrate this, calculate the surface area to volume ratio for particles in part F and G. Which particle has the higher surface area to volume ratio?

$$\text{Part F: } \frac{SA}{V} = \frac{3.142 \times 10^4 \mu m^2}{5.236 \times 10^5 \mu m^3} = 0.06 \frac{1}{\mu m} \text{ or } 6 \times 10^4 \frac{1}{m}$$

$$\text{Part G: } \frac{SA}{V} = \frac{3.142 \times 10^4 nm^2}{5.236 \times 10^5 nm^3} = 0.06 \frac{1}{nm} \text{ or } 6 \times 10^7 \frac{1}{m}$$

Materials with high surface area to volume ratios react at much faster rates compared to materials with low surface area to volume ratios. This is one of the reasons that Nano particles are highly desired for chemical reactions.