**Pre-Activity Problem Set Answer Key**

## Answer the following questions.

1. What is the chemical equation for complete combustion?

Fuel + O2 🡪 CO2 + H2O

1. What pollutants might result if incomplete combustion is occurring?

CO, VOCs, particulate matter (and still CO2 and H2O)

1. Is NOx formed from the fuel itself? If not, where does it come from? Yes or No

Thermal NOx is formed form the N2 already present in the air (air ~ 21% O2 and 79% N2).

1. Which fuel has a higher energy content? Gasoline or Diesel

Answer the following questions using the example data in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Independent Variables** | | | **Dependent Variables  (concentrations observed at tailpipe)** | | |
| **Fuel** | **Formula** | **Combustion temperature (°C)** | **CO2 (ppm)** | **VOC (ppm)** | **NOx (ppm)** |
| Case 1: Gasoline | C8H18 | 1500 | 3000 | 30 | 20 |
| Case 2: Diesel | C12H23 | 1900 | 3000 | 50 | 40 |
| Case 3: Ethanol | C2H5OH | 1500 | 4000 | 10 | 20 |

1. What is similar about the chemical formulas for all of the fuel sources?

All contain carbon and hydrogen.

1. What is different about ethanol, and why might that difference result in lower VOCs?

Ethanol has oxygen in the fuel, which facilitates more complete combustion and therefore fewer VOCs.

1. Which requires more oxygen to reach complete combustion? Gasoline or diesel? And, why?

Diesel, because it contains more carbon, or a higher carbon/hydrogen ratio; you need two oxygens for each carbon to get to CO2.

1. Which fuel type results in the most NOx and why?

Diesel, because of the higher combustion temperature.

1. In the following table, circle the **A** or **B** that best completes the row. Then explain your rationale.

|  |  |  |
| --- | --- | --- |
| **Claim** | **Evidence** | **Reason** |
| Vehicle 1 produces more total pollutants than vehicle 2. | We observe higher CO2 *and* higher VOCs in the vehicle 1 data. | 1. **Vehicle 1 has an older engine.** 2. **Vehicle 1 has a larger engine.** |
| Vehicle 2 exhibits more complete combustion than vehicle 1. | 1. **We observe more VOCs from vehicle 1 than vehicle 2.** 2. **We observe more VOCs from vehicle 2 than vehicle 1.** | Vehicle 2 is newer and operating more efficiently, therefore it is displaying more complete combustion. |
| 1. **The combustion in vehicle 1 is hotter.** 2. **The combustion in vehicle 2 is hotter.** | We observe more NOx from vehicle 1 than vehicle 2. | Vehicle 1 has a diesel engine. |

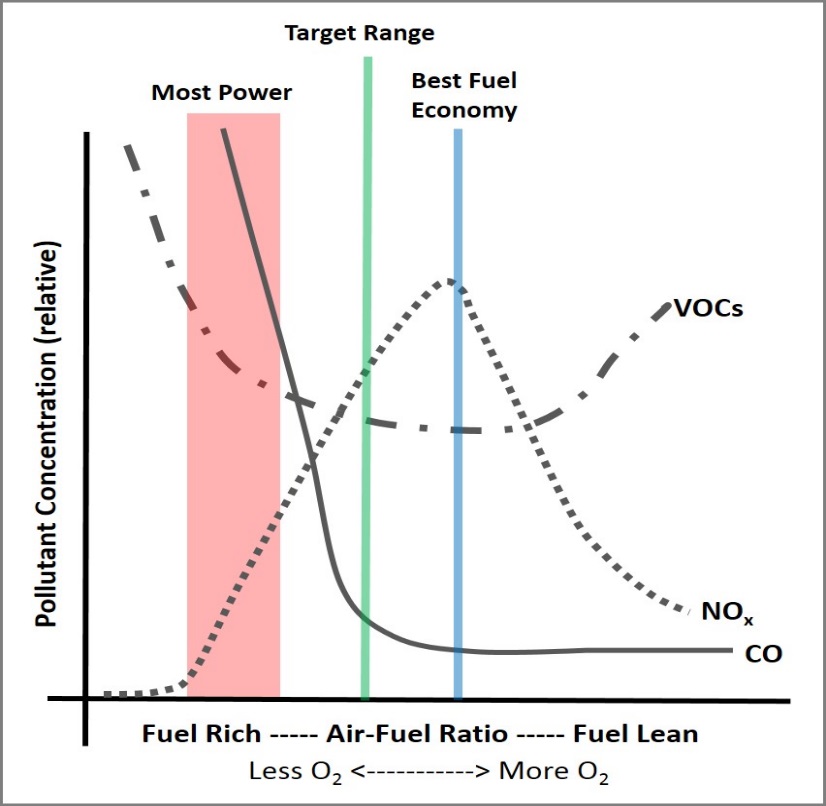
**Explanations**

Row 1: A larger engine uses more fuel, which results in more overall emissions, while an older engine may run poorly and may exhibit more incomplete combustion, but not necessarily more emissions.

Row 2: More incomplete combustion leads to more VOCs.

Row 3: Diesel engines run at a hotter temperature and typically produce more NOx.

**CHALLENGE QUESTION**



**CO2**

1. To the air-fuel ratio plot on the right, add a line for CO2.

Explanation of CO2 line placement (the red line). Moving from left to right:

**CO2**

1. To begin with, CO2 will be at a minimum.
2. It will increase as more O2 is added.
3. It will plateau as CO reaches a minimum (and achieves more complete combustion).
4. As the VOCs increase, the CO2 decreases slightly.