The Impact of Metal Processing on the Global Atmospheric Oxygen Budget
[Report 08/11/2019]

Raine Raynor '21

The global oxygen budget tracks atmospheric oxygen sinks and sources resulting from processes on land and in oceans. Climate scientists use the oxygen budget to project future atmospheric carbon dioxide buildup and learn more about the carbon cycle. My project adds detail to existing oxygen budget estimates by investigating the impact of industrial activities on atmospheric oxygen levels. This summer, I have been teaching myself about what happens during mining and refinement of major industrial metals. I then used my knowledge of these processes and reactions to quantify estimates for annual oxygen and carbon dioxide fluxes caused by the processing of iron and steel, sulfur and sulfuric acid, aluminum, and copper during the years 1990-2016.

Iron and steel
Iron is mined in the form of oxide ores hematite and magnetite. These are smelted in a blast furnace to produce hot pig iron. Ore, coking coal, and limestone are thrown together into the furnace, where hot air and high temperatures oxidizes the coke to carbon monoxide, which then reduces iron ore, producing pig iron and carbon dioxide. This results in an oxygen sink ranging from $2.11 \times 10^8 - 5.00 \times 10^8$ metric tons per year (1990-2016). Additionally, $5.81 \times 10^8 - 1.37 \times 10^9$ metric tons of carbon dioxide have been emitted annually during the same years due to smelting; however, these emissions may be already counted as fossil fuel emissions due to their origin in coking coal.

Most iron produced by the blast furnace is further refined into steel using a basic oxygen furnace. In the BOF, oxygen is blown over hot iron metal, removing impurities (manganese, silicon, carbon, and phosphorus) through oxidation. This results in an oxygen sink ranging from $1.72 \times 10^8 - 4.07 \times 10^8$ metric tons per year (1990-2016). Additional refinement used to produce specific steel alloys does not impact atmospheric oxygen levels.

Sulfur and sulfuric acid
Since 2002, sulfur has mainly been mined in the form of hydrogen sulfide from natural gas, oil sands, and petroleum. Elemental sulfur is recovered from hydrogen sulfide through the Claus process, which uses oxygen to produce sulfur and water. The Claus process results in an annual oxygen sink of ranging from $1.13 \times 10^7 - 2.33 \times 10^7$ metric tons (1990-2016).

Additionally, about 90% of sulfur is further refined through the contact process to sulfuric acid. In the contact process, oxygen reacts with elemental sulfur to form sulfur trioxide, which is then mixed with sulfuric acid and water to produce additional sulfuric acid. This sinks about $1.47 \times 10^8 - 1.99 \times 10^9$ metric tons of oxygen a year from the atmosphere (1990-2016).

Aluminum
Aluminum is mined as the mineral bauxite and converted first to alumina via the Bayer process before undergoing the Hall-Héroult process and becoming pure aluminum. Hall-Héroult uses a carbon anode and electrolysis to extract aluminum from a molten salt bath containing dissolved alumina in it. Neither the Bayer nor the Hall-Héroult process has any effect on the oxygen budget; however, the Hall-Héroult process does produce approximately $2.35 \times 10^7 - 7.10 \times 10^7$ metric tons of carbon dioxide a year (1990-2016).

Copper
I have not yet determined the oxygen sink created by copper, as my fellowship has two weeks left on it. I plan on quantifying copper's effects in the upcoming weeks.

Faculty Mentor: Mark Battle
Funded by the E. O. LaCasce Jr. Physics Fund Fellowship

References: See attached to email