Unit 5. Modern CO_2 Accumulation
CO_2 Production from Burning Fossil Fuels
Student Worksheet

A. How much carbon dioxide is produced when coal is burned?

1. Different types of coal can be compared by the amount of CO_2 emitted per unit of energy output. This is typically expressed as weight (in pounds) of CO_2 emitted per million BTU[1] (or 1,000,000 BTU) of heat energy produced.

The amount of CO_2 gas emitted when coal is burned is related to the carbon content of the coal. Heat is produced when carbon and hydrogen are combined with oxygen during burning. In Unit 4, Fossil Fuel Formation, you calculated the weight of coal (in pounds) that would need to be burned to produce 1 million BTU of energy.

Compare the weight of coal burned to the weight of CO_2 emitted, for each rank of coal.

a. Which weighs more – the coal that was burned or the CO_2 that was produced? _____

b. Propose a reason why the CO_2 gas emitted from the burning of coal weighs more than the coal that was burned:

c. Which rank of coal has the *highest* CO_2 emissions per million BTU? _____

d. Which rank of coal has the *lowest* CO_2 emissions per million BTU? _____

Coal Rank	Carbon Content (%)	Weight of coal (in pounds) burned to produce 1 million BTU of energy	Weight of CO_2 (in pounds) emitted per 1 million BTU of energy (for U.S. coal)
Lignite	46 - 60%	120 to 181.8 lb	215.4 lb
Sub-bituminous coal	46 - 60%	76.9 to 120 lb	214.3 lb
Bituminous coal	46 - 86%	66 to 90.9 lb	205.7 lb
Anthracite coal	86 - 98%	64 to 74 lb	228.6 lb

When coal is burned, carbon atoms are moved from the geosphere to the atmosphere. Each atom of carbon in the coal combines with two atoms of oxygen to produce carbon dioxide (CO_2). The atomic weight of carbon is 12, and the atomic weight of oxygen is 16. Adding two oxygen atoms (16 + 16) to each carbon atom (12) produces CO_2 (or 12 + 16 + 16= 44). So carbon dioxide has an atomic weight of 44, which is approximately 3.667 times heavier than a carbon atom of atomic weight 12.

Using the data in the table above, anthracite coal averages about 90% carbon. Burning about 70 pounds of anthracite will produce about 228.6 pounds of CO_2. Since 90% of 70 pounds is about 63 pounds, there are about 63 pounds of carbon atoms in 70 pounds of anthracite coal. Multiply 63 pounds by 3.667 = 231 pounds of carbon dioxide. This calculated 231 pounds of CO_2 is a little more than the 228.6 pounds in the table above, which is the approximate observed weight of CO_2 produced by burning about 70 pounds of anthracite coal. The slight difference between 231 lb of CO_2 and 228.6 lb of CO_2 is due to a small percentage of the carbon in the coal not being oxidized during combustion[2].

2. In 2012, 1,016.4 million short tons of coal (1,016,400,000 tons) were mined in the United States, according to the U.S. Energy Information Administration. (1 short ton = 2000 lb.)
Calculate how many BTU of energy would be produced by burning this much coal.
Note on calculations: *First, convert 1,016.4 million short tons of coal to pounds of coal. (Multiply by 2000 lb/short ton.)*
Then, for simplicity, assume all of this coal was bituminous, with about 80 pounds of coal burned to produce 1 million BTU. *Then divide your result by 80 pounds of coal per 1 million BTU, to see how many BTU of energy would be produced.*

How many BTU of energy would be produced by burning this much coal? _____

3. Now, calculate the number of short tons of carbon dioxide that would be released into the atmosphere, assuming that all of this coal was burned.
Note on calculations: *Take your result from the question above, for bituminous coal, and multiply by 205.7 lb/1 million BTU. Then convert your answer from pounds to short tons. (Multiply by 1 short ton/2000 lb).*

How many short tons of CO_2 would be released into the atmosphere if all of the coal mined in the United States in 2012 were burned?

_____

4. What effect do you think this much carbon dioxide would have on the atmosphere? (Keep in mind that this is the amount for burning coal only (not including petroleum products), and for one year only, and for only the U.S.)

_____

5. Comparing the amount of CO_2 emitted when fossil fuels are burned.

Fossil fuel	Weight of CO_2 (in pounds) emitted per 1 million BTU of energy
Lignite	215.4 lb
Sub-bituminous coal	214.3 lb
Bituminous coal	205.7 lb
Anthracite coal	228.6 lb
Diesel fuel and heating oil	161.3
Gasoline	157.2
Propane	139.0
Natural gas (methane)	117.0

a. Which fossil fuel in the table above produces the *most* CO_2 when burned? _____

b. Which fossil fuel produces the *least* CO_2 when burned? _____

6. A gallon of gasoline weighs 6.073 lb. When a gallon of gasoline is burned, it produces about 19.64 pounds of CO_2.

How many pounds of CO_2 do you produce when you burn a full tank of gasoline (about 20 gallons)?

_____

7. Each part per million (ppm) concentration of CO_2 in the atmosphere is the equivalent to a global atmospheric mass of about 2.13 billion *metric tons* of CO_2. (1 *metric ton* = 1000 kg, and 1 kg = 2.20462 lb, so 1 *metric ton* = 2204.62 lb.) In 1800, around the time of the Industrial Revolution, the atmospheric concentration of CO_2 in the atmosphere was about 280 ppm. In the summer of 2014, there was more than 400 ppm of CO_2 in the atmosphere.

a. How many billion metric tons of CO_2 have been added to the atmosphere between 1800 and 2014?

_____

b. How many billion metric tons of CO_2 are currently in the atmosphere?

_____

8. In 1966, the atmospheric concentration of CO_2 was 321 ppm. In 2014, the atmospheric concentration of CO_2 was 400 ppm. This is an increase of 79 ppm. Each ppm is equivalent to 2.13 billion metric tons of CO_2.

Year	Atmospheric CO_2 concentration	Weight of CO_2 (in billion metric tons)
1966	321 ppm	683.73
2014	400 ppm	852.00
Amount of increase from 1966 to 2014	79 ppm	**168.27**

The production of CO_2 emissions worldwide is listed in the table below, indicating that from 1966 to 2006, 225 billion metric tons of CO_2 were emitted. However, the atmospheric concentration of CO_2 did not increase by 225 billion metric tons. It only increased by 168.27 billion metric tons.

Source of CO_2	Weight of CO_2 (in billion metric tons)
Coal	86
Oil	98
Natural gas	36
Other	5
Total	225

How do you account for the difference between CO_2 emissions and the change in atmospheric concentration of CO_2? Where did the excess CO_2 go? List the possible sinks that may have absorbed some of this CO_2.

Footnotes

[1] BTU stands for **B**ritish **T**hermal **U**nits. BTU is a commonly used measure of energy in heating and air conditioning. It is defined as the amount of energy needed to heat (or cool) 1 pound of water by 1 degree Fahrenheit.

[2] For more information, see http://www.eia.gov/tools/faqs/faq.cfm?id=82&t=11 and http://www.eia.gov/coal/production/quarterly/co2_article/co2.html

References

http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11
http://www.eia.gov/coal/production/quarterly/co2_article/co2.html
http://theenergylibrary.com/node/12170