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CHEM 001A

Flipped Classroom Activity #4

"Liquid Coal"

There is a substantial amount of research being devoted to finding fuel sources that can be used to replace petroleum-based fuels, the most widely used being gasoline and diesel. Proposed efforts to replace petroleum-based fuels range from expanding the fleet of electric cars (charged using electricity generated from renewable sources such as wind and solar), expanding the fleet of cars powered by fuel cells which operate on hydrogen gas, and/or expanding the fleet of cars that operate on traditional fuel sources that are derived from more abundant local resources (e.g., corn ethanol, biodiesel, etc.).

Coal also continues to be a potential fuel source, and researchers are trying to find ways in which we can better utilize this resource. Since coal cannot be used to power our current ground fleet automobile and trucks, it must be converted in a liquid fuel if it is going to be used to supplant petroleum fuels.

Read the attached journal article by D. Hildebrandt et al (*Science*, 2009, 323, pg. 1680-1681) to get an overview of how coal might be converted to liquid fuel. Also read the introduction of the attached paper by R. Agrawal et al (Proceedings of the National Academy of Science, 2007, 104, pg. 4828-4833) to familiarize yourself with the general issues associated with creating liquid fuels from non-petroleum sources.

Questions:

1. What is coal?

2. What are the advantageous of converting coal to a liquid fuel?

3. Hildebrandt et al propose a reaction scheme (reaction scheme 2 pg. 1681, bottom reaction in Figure 1) in which coal is converted to hydrocarbon fuel (-CH_2-). What are the advantages of this proposed reaction scheme compared to the traditional reaction scheme (reaction scheme 1 pg. 1680, top reaction in Figure 1)?

4. The authors depict the new proposed reaction scheme in the following way:

CO_2 and H_2 (supplemental H_2 & CO_2 can be fed into the reaction to enhance the production of the final liquid fuel)

$$3C(s) + 6H_2O(l) \rightarrow 3CO_2(g) + 6H_2(g) \rightarrow 2(\text{-}CH_2\text{-})(l) + 4H_2O(l) + CO_2(g)$$

If you write the reactions in a stepwise fashion, what is the overall net reaction?

step 1: $3C(s) + 6H_2O(l) \rightarrow 3CO_2(g) + 6H_2(g)$

step 2: $3CO_2(g) + 6H_2(g) \rightarrow 2(-CH_2-)(l) + 4H_2O(l) + CO_2(g)$

overall reaction = $\boxed{}$

5. The largest component of gasoline is liquid octane (C_8H_{18}). If we assume the proposed coal-to-liquid fuel reaction process is used to make octane-rich liquid fuel, what would be the balanced reaction sequence? (hint: use fractional mole coefficients if necessary to balance the equations).

$\boxed{}\ C(s) + \boxed{}\ H_2O(l) \rightarrow \boxed{}\ CO_2(g) \boxed{}\ H_2(g)$

$\boxed{}\ CO_2(g) + \boxed{}\ H_2(g) \rightarrow \boxed{1}\ C_8H_{18}(l) \boxed{}\ H_2O \boxed{1}\ CO_2(g)$

6. The authors state that the goal would be to use this process to make 80,000 barrels of liquid hydrocarbon fuel per day. How many tons of coal would be required to produce this much liquid fuel? Use the balanced equation from question 4:

$3C(s) + 6H_2O(l) \rightarrow 3CO_2(g) + 6H_2(g) \rightarrow 2(-CH_2-)(l) + 4H_2O(l) + CO_2(g)$

1 barrel = 42 gallons

1 gallon = 3.78 L

density of liquid fuel = 0.700 g/mL (assume this is the density of $-CH_2-$)

1 ton = 2,000 lbs

1 lb = 0.45 kg

final answer: $\boxed{}$

7. What are the advantages and disadvantages of using coal to produce liquid fuels? If you had to decide whether or not to invest federal funds in developing the CLT (coal-to-liquids) technology, would you support these efforts?