

### Exam 1 Practice Problems

#### 1. The Hydrological Cycle.

- a. The volume of water evaporated from the world's oceans each year is  $5.05 \times 10^5$  km<sup>3</sup>. The evaporation process can be described by the following chemical reaction:



If the total incident radiation from the sun is  $1.74 \times 10^{17}$  W, what fraction of the Earth's incoming radiation is used for evaporation? (The density of water is 1.00 g/ml. Note that the letters l and g in parentheses indicate liquid and gas, respectively.)

- b. Write an equation and indicate the change in enthalpy ( $\Delta H$ ) for the condensation of water to form clouds. Is this process endothermic or exothermic? There are several isotopes of hydrogen and oxygen that may be present in water. These are given in the table below. For each isotope, indicate the number of protons, neutrons, and electrons.

Element	Symbol	Exact Mass (amu)	Abundance (%)
Hydrogen	<sup>1</sup> H	1.007825	99.99
	<sup>2</sup> H	2.014102	0.015
Oxygen	<sup>16</sup> O	15.994915	99.76
	<sup>18</sup> O	17.999159	0.20

- c. Determine the average atomic mass of oxygen from the data in the table.
- d. Provide chemical formulas, including identification of the isotopes, for "normal" water and one possible form of "heavy" water.
- e. If global warming increases the temperature at the pole, what will be the effect on the isotopic signature of the precipitation there? Will it be heavier or lighter? Explain why this occurs.
- f. The Greenland ice sheet is 2.3 km thick and covers an area of 2.18 million km<sup>2</sup>. If the ice sheet melts and the water flows into the ocean, by how much would sea level rise? Assume that oceans cover 70% of the Earth's  $5.1 \times 10^8$  km<sup>2</sup> surface area. Note that the density of ice is 0.9167 g/ml, slightly less than that of liquid water.
- g. Scientists speculate that this process might trigger abrupt climate change. What is abrupt climate change? What evidence is there that it has occurred in the past? Describe a mechanism by which melting of Greenland ice might lead to abrupt climate change.

2. In the tropics, sugarcane can be used as a source material for producing ethanol for use as a biofuel. In this problem, you will assess the costs and benefits of producing ethanol from sugarcane.
- In Brazil, one hectare ( $1 \text{ ha} = 10,000 \text{ m}^2$ ) of land can produce 58 metric tons ( $1 \text{ ton} = 1000 \text{ kg}$ ) of sugarcane per year. The raw sugarcane is 13.5% sucrose by mass. How many kilograms of sucrose can be produced per hectare per year?
  - Sucrose is a sugar with the chemical formula  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ . It can be fermented in the presence of water to form ethanol ( $\text{C}_2\text{H}_5\text{OH}$ ) and  $\text{CO}_2$ . Write a balanced chemical reaction for this process.
  - Ethanol can be produced from sucrose with an efficiency (yield) of 76%. Determine the volume of ethanol in liters produced per hectare of land each year. (The density of ethanol is  $0.789 \text{ g/ml}$ .)
  - Write a chemical equation for the combustion of ethanol and calculate the heat of reaction ( $\Delta H$ , in  $\text{kJ/mol}$ ) for this process. (The formula for ethanol can also be written  $\text{CH}_3\text{CH}_2\text{OH}$ . You may use the table of bond energies from the reading. The same table will be provided for the exam.)
  - How much energy can be produced each year from the ethanol from one hectare of land?
  - The energy balance is defined as the amount of energy produced from ethanol combustion divided by the amount of energy used in the production process (including in cultivation, harvesting, processing, fermentation, etc.). One reason sugarcane ethanol has such a high energy balance is because the stalks and other byproducts can be burned to provide power for processing. To grow 1 ha of sugarcane, only about 325 kg diesel fuel is needed, which is used in cultivation and transportation. Assuming that diesel fuel has a heat of combustion (per unit mass) of  $44.8 \text{ kJ/g}$ , what is the energy balance of sugarcane ethanol?
  - Compare the net change in atmospheric  $\text{CO}_2$  from production and use of ethanol as a biofuel to that resulting from combustion of enough diesel fuel to produce an equivalent amount of energy. (Base your answer on the amount of energy produced from 1 ha of sugarcane. Assume diesel fuel has the chemical formula  $\text{C}_{12}\text{H}_{26}$ .) By how much are  $\text{CO}_2$  emissions reduced by using ethanol from sugarcane relative to burning diesel?
  - Which has a higher energy balance and/or lower net  $\text{CO}_2$  emissions, ethanol from sugarcane or that produced in the US from corn? Discuss reasons for the differences. In your opinion, is ethanol produced from sugarcane in Brazil a viable alternative energy source?