

## Energy Stoichiometry! ☺

Enthalpy is commonly measured in  $\text{kJ/mol}_{\text{rxn}}$ , but what is a mole of reaction?

$1 \text{ mol}_{\text{rxn}} = 1 \text{ mole of reaction} = \text{stoichiometric \# of reactants/ products}$

For the combustion of ethane:  $2 \text{C}_2\text{H}_6 + 7 \text{O}_2 \rightarrow 4 \text{CO}_2 + 6 \text{H}_2\text{O} + 3,120 \text{ kJ}$

When 1 mole of reaction has occurred,

- 2 mol of  $\text{C}_2\text{H}_6$  reacted
- 7 mol of  $\text{O}_2$  reacted
- 3120 kJ energy released
- 4 mol of  $\text{CO}_2$  were produced
- 6 mol of  $\text{H}_2\text{O}$  were produced

Luckily for us, the enthalpy of a reaction, when measured in  $\text{kJ/mol}_{\text{rxn}}$ , can act as a conversion factor between the amount of chemicals which react and the energy that is absorbed or released by the reaction!

**Example 1:** Give the following reaction,  $2 \text{Fe} + 3 \text{CO}_2 \rightarrow 3 \text{CO} + \text{Fe}_2\text{O}_3$  ( $\Delta H = +24.7 \text{ kJ/mol}_{\text{rxn}}$ ) what energy change occurs when 6.0 moles of carbon dioxide react?

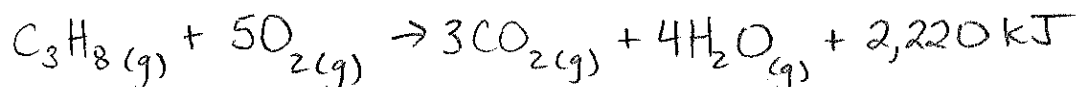
$$6.0 \text{ mol CO}_2 \times \frac{1 \text{ mol}_{\text{rxn}}}{3 \text{ mol CO}_2} \times \frac{24.7 \text{ kJ}}{1 \text{ mol}_{\text{rxn}}} = \boxed{49 \text{ kJ}}$$

**Example 2:** Give the following reaction,  $\text{N}_2 + 3 \text{H}_2 \rightarrow 2 \text{NH}_3$  ( $\Delta H = -324 \text{ kJ/mol}_{\text{rxn}}$ ) what mass of hydrogen must have reacted if 525 kJ of heat were released?

$$-525 \text{ kJ} \times \frac{1 \text{ mol}_{\text{rxn}}}{-324 \text{ kJ}} \times \frac{3 \text{ mol H}_2}{1 \text{ mol}_{\text{rxn}}} \times \frac{2.016 \text{ g H}_2}{1 \text{ mol H}_2} = \boxed{9.80 \text{ g H}_2}$$

## Independent Practice

1. The heat of combustion of gaseous propane ( $\text{C}_3\text{H}_8$ ) is  $-2220 \text{ kJ/mol}_{\text{rxn}}$ .
  - a. Write the balanced thermochemical equation for the combustion of propane.

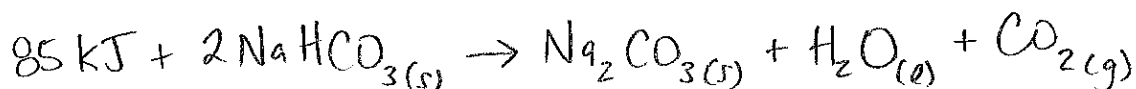


- b. What is the sum of the coefficients when the reaction is written and balanced? 13
- c. Is the reaction endothermic or exothermic? exo
- d. What mass of propane must be burned to release 5,550 kJ of heat?

$$-5,550 \text{ kJ} \times \frac{1 \text{ mol}_{\text{rxn}}}{-2,220 \text{ kJ}} \times \frac{1 \text{ mol C}_3\text{H}_8}{1 \text{ mol}_{\text{rxn}}} \times \frac{44.094 \text{ g C}_3\text{H}_8}{1 \text{ mol C}_3\text{H}_8} = \boxed{112 \text{ g C}_3\text{H}_8}$$

2. Solid sodium hydrogen carbonate decomposes into solid sodium carbonate, liquid water, and carbon dioxide gas. ( $\Delta H_{\text{rxn}} = +85 \text{ kJ/mol}_{\text{rxn}}$ )

a. Write the balanced thermochemical equation for this reaction.



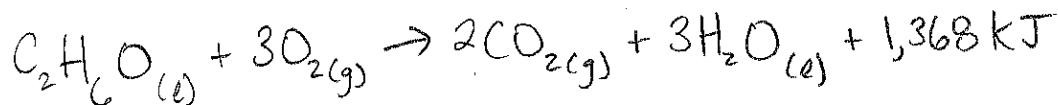
b. Is the reaction endothermic or exothermic? endo

c. What is the energy change that occurs when 2.25 mol of  $\text{NaHCO}_3(s)$  decomposes?

$$2.25 \text{ mol NaHCO}_3 \times \frac{1 \text{ mol}_{\text{rxn}}}{2 \text{ mol NaHCO}_3} \times \frac{85 \text{ kJ}}{1 \text{ mol}_{\text{rxn}}} = \boxed{97 \text{ kJ}}$$

3. When liquid ethanol,  $\text{C}_2\text{H}_6\text{O}(l)$ , burns, it reacts with  $\text{O}_2(g)$  to produce  $\text{CO}_2(g)$  and  $\text{H}_2\text{O}(l)$  and 1368 kJ of heat.

a. Write the balanced thermochemical equation for this reaction.



b. Is the reaction endothermic or exothermic? exo

c. If the reaction takes place at not STP  $22^\circ\text{C}$  and  $0.92 \text{ atm}$ , what volume of carbon dioxide gas will be produced from this reaction if 998.6 kJ of heat is released?

$$-998.6 \text{ kJ} \times \frac{1 \text{ mol}_{\text{rxn}}}{-1,368 \text{ kJ}} \times \frac{2 \text{ mol CO}_2}{1 \text{ mol}_{\text{rxn}}} = 1.46 \text{ mol CO}_2$$

$$V = \frac{nRT}{P} = \boxed{38 \text{ L CO}_2}$$

$$= \frac{(1.46 \text{ mol})(0.08206 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}})(295 \text{ K})}{0.92 \text{ atm}}$$

4. When barium hydroxide octahydrate,  $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$  is mixed in a beaker with ammonium thiocyanate,  $\text{NH}_4\text{SCN}$ , a reaction occurs. The beaker becomes very cold.

a. Have the surroundings gained or lost heat? How do you know?

lost heat, b/c the beaker got colder

b. Has the system gained or lost heat? How do you know?

gained energy, b/c the surroundings lost energy

c. Is the reaction endothermic or exothermic? endo