Name ____________________ **Honors Chemistry** **___/___/___**

Heats of Reaction - Answers

Homework:

1. Define activation energy – **the amount of energy needed to start a chemical reaction**

2. Define catalyst – **substances used to reduce the amount of activation energy needed to start a reaction. Catalysts are used to speed up reactions but are not used up in the reaction**

3. Define standard enthalpy of formation ($\Delta H_f°$) – **the change in enthalpy that accompanies the formation of one mole of a compound from its elements with all substances in their standard states**

4. The degree symbol (°) on a thermodynamic function indicates: **The degree symbol (°) on a thermodynamic function indicates that the corresponding process has been carried out under standard conditions.**

5. Define Standard Conditions for:
   a. pressure – **1 atm**   b. temperature - **25°C or 298 K**   c. molarity (M) – **1 M**

6. What is the heat of formation value for elements in their standard state?
   Elements in their standard state have $\Delta H_f° = 0$

7. Rewrite the following equations with energy included. Indicate if the reaction is **endothermic or exothermic**.

a. $2NO + O_2 \rightarrow 2NO_2$ $\Delta H° = -27$ kcal

$2NO + O_2 \rightarrow 2NO_2 + 27$ kcal
endothermic or **exothermic**

b. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ $\Delta H° = -890$ kJ

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + 890$ kJ
endothermic or **exothermic**

c. $2H_2O \rightarrow 2H_2 + O_2$ $\Delta H° = 571.6$ kJ

$2H_2O + 571.6$ kJ $\rightarrow 2H_2 + O_2$
endothermic or exothermic

d. $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ $\Delta H° = 2870$ kJ

$6CO_2 + 6H_2O + 2870$ kJ $\rightarrow C_6H_{12}O_6 + 6O_2$
endothermic or exothermic

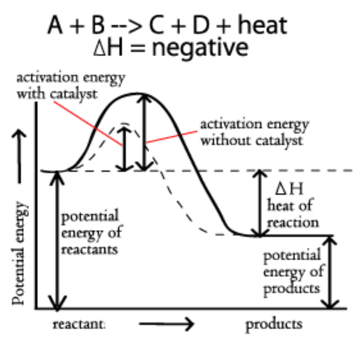
e. $2K + 2H_2O \rightarrow 2KOH + H_2$ $\Delta H° = -393$ kJ

$2K + 2H_2O \rightarrow 2KOH + H_2 + 393$ kJ
endothermic or **exothermic**

f. $TiO_2 + 2Cl_2 \rightarrow TiCl_4 + O_2$ $\Delta H° = 140.5$ kJ

$TiO_2 + 2Cl_2 + 140.5$ kJ $\rightarrow TiCl_4 + O_2$
endothermic or exothermic

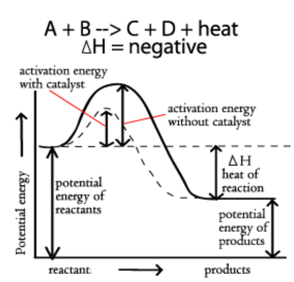
8. The heat of formation for Cu_2S is -79.5 kJ/mol, for S its 0 kJ/mol and for CuS its -53.1 kJ/mol.
   $Cu_2S + S \rightarrow 2CuS$



a. What is the change in enthalpy for this reaction? **$\Delta H° = -26.7$ kJ**
b. Is this reaction **exothermic** or endothermic ? Circle One.
c. Draw an energy diagram for this reaction. Label potential energy of the reactants, potential energy of the products, ΔH°, and activation energy.
d. Which has higher enthalpy, the **reactants** or the products of this reaction?
e. Re-write the equation from above with the ΔH° value as a reactant or product, whichever is correct.
   $Cu_2S + S \rightarrow 2CuS + 26.7$ kJ

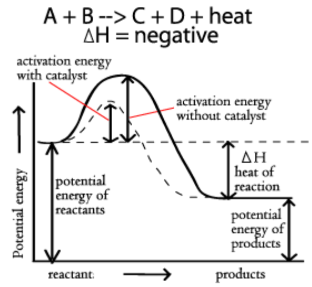
9. Determine the heat of reaction for the following reaction as water vapor cools to form liquid water. The heat of formation for H_2O (g) is -241.82 kJ/mol and for H_2O (l) it is -285.83 kJ/mol.

H_2O (g) $\rightarrow H_2O$ (l)
-241.82 → -285.83
$\Delta H° = \sum\Delta H_f°$ (products) - $\sum\Delta H_f°$ (reactants)
$\Delta H° = -285.83 - (-241.82)$
$\Delta H° = -44.01$ kJ



a. What is the change in enthalpy for this reaction? **$\Delta H° = -44.01$ kJ**
b. Is this reaction **exothermic** or endothermic ? Circle One.
c. Draw an energy diagram for this reaction. Label potential energy of the reactants, potential energy of the products, ΔH°, and activation energy.
d. Which has higher enthalpy, the **reactants** or the products of this reaction? Circle One.
e. Re-write the equation from above with the ΔH° value as a reactant or product, whichever is correct.
   H_2O (g) $\rightarrow H_2O$ (l) + 44.01 kJ

10. The heat of formation of H_2O_2 is -187.6 kJ/mol, the heat of formation of H_2O is -285.83 kJ/mol, and the heat of formation of O_2 is 0 kJ/mol. Determine the heat of reaction for the decomposition of H_2O_2. Draw an energy diagram for this reaction.



$2H_2O_2 \rightarrow 2H_2O + O_2$

2 (-187.6) → 2 (-285.83) + 0
-375.2 → -571.66
$\Delta H° = \sum\Delta H_f°$ (products) - $\sum\Delta H_f°$ (reactants)
ΔH° = -571.66 – (-375.2)
ΔH° = -196.5 kJ

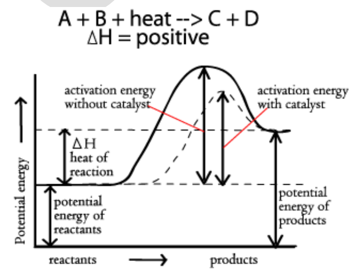
a. What is the change in enthalpy for this reaction? **ΔH° = -196.5 kJ**
b. Is this reaction **exothermic** or endothermic ? Circle One.
c. Draw an energy diagram for this reaction. Label potential energy of the reactants, potential energy of the products, ΔH°, and activation energy.
d. Which has higher enthalpy, the **reactants** or the products of this reaction? Circle One.
e. Re-write the equation from above with the ΔH° value as a reactant or product, whichever is correct.
$2H_2O_2 \rightarrow 2H_2O + O_2$ + 196.5 kJ

11. In the engine of your car, nitrogen and oxygen combine to form nitrogen oxides, chemicals that contribute to pollution. Below is a reaction that produces nitrogen dioxide from previously formed nitrogen monoxide. Determine the ΔH value for this reaction using the heats of formation given. Draw an energy diagram for this reaction.

Substance	$\Delta H_f°$ (kJ/mol)
NO_2 (g)	+33.2
NO (g)	+90.2
O_2 (g)	0

$2NO_2\ (g) \rightarrow 2NO\ (g) + O_2\ (g)$

2 (33.2) → 2 (90.2) + 0
66.4 → 180.4
$\Delta H° = \sum\Delta H_f°$(products) - $\sum\Delta H_f°$(reactants)
ΔH° = 180.4 – 66.4
ΔH° = 114.0 kJ



a. What is the change in enthalpy for this reaction? **ΔH° = 114.0 kJ**
b. Is this reaction exothermic or **endothermic** ? Circle One.
c. Draw an energy diagram for this reaction. Label potential energy of the reactants, potential energy of the products, ΔH°, and activation energy.
d. Which has higher enthalpy, the reactants or the **products** of this reaction? Circle One.
e. Re-write the equation from above with the ΔH° value as a reactant or product, whichever is correct.
$2NO_2$ (g) + 114.0 kJ → 2NO (g) + O_2 (g)

12. At constant temperature and pressure, the heats of formation for $H_2O(g)$, $CO_2(g)$ and $C_2H_6(g)$ are given to the right. What is the ΔH for **1 mole of C_2H_6** gas to oxidize to carbon dioxide gas and water vapor (temperature and pressure are held constant)?

Species	$\Delta H_f°$ (kJ/mole)
$H_2O(g)$	-251
$CO_2(g)$	-393
$C_2H_6(g)$	-84

$C_2H_6 + 7/2\ O_2 \rightarrow 2CO_2 + 3H_2O$
-84 + 0 → 2(-393) + 3(-251)
-84 → -1539
$\Delta H° = \sum\Delta H_f°$(products) - $\sum\Delta H_f°$(reactants)
ΔH° = -1539 – (-84)
ΔH° = -1455 kJ

13. $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(l)$ ΔH° = - 889.1 kJ

Species	$\Delta H_f°$ (kJ/mole)
$H_2O(l)$	- 285.8 kJ / mole
$CO_2(g)$	- 393.3 kJ / mole

What is the standard heat of formation of methane, $\Delta H_f°$ $CH_4(g)$, as calculated from the data above?

$\Delta H° = \sum\Delta H_f°$(products) - $\sum\Delta H_f°$(reactants)
-889.1 = [(-393.3) + 2(-285.8)] – CH_4
-889.1 = [-964.9] – CH_4
75.8 = -CH_4
CH_4 = -75.8 kJ

14. $O_3(g) + NO(g) \rightarrow O_2(g) + NO_2(g)$

Species	$\Delta H_f°$ (kJ/mole)
$O_3(g)$	143
NO(g)	90.
$NO_2(g)$	33

Consider the reaction represented above.
Referring to the data in the table to the right, calculate the standard enthalpy change, ΔH°, for the reaction at 25°C. Be sure to show your work.

143 + 90 → 0 + 33
233 → 33
$\Delta H° = \sum\Delta H_f°$(products) - $\sum\Delta H_f°$(reactants)
ΔH° = 33 – (233)
ΔH° = -200. kJ

15. $C_7H_{16}(l) + 11\ O_2(g) \rightarrow 7\ CO_2(g) + 8\ H_2O(l)$

Species	$\Delta H_f°$ (kJ/mole)
$H_2O(l)$	- 285.8 kJ / mole
$CO_2(g)$	- 393.3 kJ / mole

The heat of combustion, $\Delta H_{comb}°$, for one mole of $C_7H_{16}(l)$ is -4.85 x 10^3 kJ. Using the information in the table below, calculate the value of $\Delta H_f°$ for $C_7H_{16}(l)$ in kJ mol^{-1}.

$\Delta H° = \sum\Delta H_f°$(products) - $\sum\Delta H_f°$(reactants)
-4850 = [7(-393.3) + 8(-285.8)] – C_7H_{16}
-4850 = [-5039.5] – C_7H_{16}
189.5 = -C_7H_{16}
C_7H_{16} = -190. kJ