Enthalpy

Sample Problems:

1. Given the equation $3\ O_{2(g)} \rightarrow 2\ O_{3(g)}$ $\Delta H = +285.4$ kJ, calculate ΔH for the following reaction. $3/2\ O_{2(g)} \rightarrow O_{3(g)}$.

Answer

Since $3/2\ O_{2(g)} \rightarrow O_{3(g)}$ is ½ of $3\ O_{2(g)} \rightarrow 2\ O_{3(g)}$ the enthalpy of the reaction will be ½ as well: ½ (+285.4kJ) = **+142.7kJ**

2. Given the equation: $2Ag_2S_{(s)} + 2H_2O_{(l)} \rightarrow 4Ag_{(s)} + 2H_2S_{(g)} + O_{2(g)}$ $\Delta H = +595.5$kJ, calculate ΔH for the following reaction.
$Ag_{(s)} + ½\ H_2S_{(g)} + ¼\ O_{2(g)} \rightarrow ½\ Ag_2S_{(s)} + ½\ H_2O_{(l)}$

Answer

In this problem, the reaction equation has been reversed and divided by four. The new enthalpy value will be the opposite sign and ¼ its original value: -1/4(+595.5kJ) **= -148.9kJ**

3. Express the following information as a chemical equation. At 25°C and at a constant pressure, dinitrogen trioxide gas decomposes to nitrogen monoxide and nitrogen dioxide gases with the absorption of 0.533kJ of heat for every gram of dinitrogen trioxide that decomposes.

Answer
+0.533kJ/g N_2O_3
0.533kJ/g (76.01g/mol) = +40.5kJ/mol
$N_2O_{3(g)} \rightarrow NO_{(g)} + NO_{2(g)}$ $\Delta H = +40.5kJ$

4. What is the enthalpy change when 12.8g $H_{2(g)}$ reacts with excess $Cl_{2(g)}$ to form $HCl_{(g)}$?
$H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$ $\Delta H = -184.6kJ$

Answer
12.8g H_2 / 2.016g/mol = 6.35mol H_2
6.35mol H_2 (-184.6kJ/mol H_2) = **$-1.17x10^3$kJ**

5. What volume of $CH_{4(g)}$, measured at 25°C and 745Torr, must be burned in excess oxygen to release $1.00x10^6$kJ of heat to the surroundings?
$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$ $\Delta H = -890.3kJ$

Answer
There is 890.3kJ given off for every mole of CH_4 burned, therefore
the moles of CH_4 needed are $1.00x10^6$kJ/(890.3kJ/mol) = 1123mol CH_4
V = nRT/P = (1123mol)(.0821)(25°C + 273.15)/(745/760) = **$2.80x10^4$L CH_4**

Calorimetry

1. Calculate the heat capacity of a sample of brake fluid if the sample must absorb 911J of heat for its temperature to rise from 15°C to 100°C.

Answer
C = q/ΔT = 911/(100-15) = **10.7J/°C**

2. A burner on an electric range has a heat capacity of 345J/K. What is the value of q, in kilojoules, as the burner cools from a temperature of 467^{o}C to a room temperature of 23^{o}C?

Answer
$q = C\Delta T = (345J/K)(23-467) = -1.53x10^{5}J =$ **-153kJ**

Molar Heat Capacity/Specific Heat

1. How much heat, in calories and kilocalories, does it take to raise the temperature of 814g of water from 18.0^{o}C to 100^{o}C?

Answer
$q = mc\Delta T = (814g)(1cal/g^{o}C)(100^{o}C - 18^{o}C) =$ **$6.67x10^{4}$cal = 66.7Cal (kcal)**

2. What mass of water, in kilograms, can be heated from 5.5^{o}C to 55.0^{o}C by $9.09x10^{10}$J of heat?

Answer
$m = q/c\Delta T = 9.09x10^{10}J / (4.180J/g^{o}C)(55.0^{o}C - 5.5^{o}C) = 4.39x10^{8}g =$ **$4.39x10^{5}$kg**

3. A 454g block of lead is at an initial temperature of 22.5^{o}C. What will be the temperature of the lead after it absorbs 4.22kJ of heat from its surroundings?

Answer
$\Delta T = q / mc \quad = 4.22x10^{3}J / (454g)(0.128J/g^{o}C) = 72.6^{o}C$
Since heat is absorbed the temperature will go up
The final temperature is 22.5^{o}C + 72.6^{o}C = **95.1^{o}C**

4. How many grams of copper can be heated from 22.5°C to 35.0°C by the same quantity of heat that can raise the temperature of 145g of H_2O from 22.5°C to 35.0°C?

Answer
(145g)(4.180J/g°C) = m(0.385J/g°C)
1574.3g
1.57kg

Bomb Calorimetry

1. A 0.8082g sample of glucose ($C_6H_{12}O_6$) is burned in a bomb calorimeter assembly, and the temperature is noted to rise from 25.11°C to 27.21°C. Determine the heat capacity of the bomb calorimeter assembly, given:
$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(l)}$
$\Delta H = -2803kJ$

Answer
moles of glucose = 0.8082g / 180.2g/mol = 0.00449mol
q = -2803kJ/mol (0.00449mol) = -12.59kJ
C = q/ΔT = 12.59kJ/2.10°C = **6.00kJ/°C**

Hess's Law of Heat Summation

1. Calculate the enthalpy change for the reaction
$C_2H_{4(g)} + H_{2(g)} \rightarrow C_2H_{6(g)}$ $\Delta H = ?$

Given:
$C_2H_{4(g)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 2H_2O_{(l)}$
$\Delta H = -1410.9kJ$
$2C_2H_{6(g)} + 7O_{2(g)} \rightarrow 4CO_{2(g)} + 6H_2O_{(l)}$
$\Delta H = -3119.4kJ$
$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$
$\Delta H = -571.6kJ$

Answer:

$C_2H_{4(g)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 2H_2O_{(l)}$
$(4CO_{2(g)} + 6H_2O_{(l)} \rightarrow 2C_2H_{6(g)} + 7O_{2(g)})/2$ (flip equation and divide by 2)
$(2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)})/2$ (divide by 2)

$C_2H_{4(g)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 2H_2O_{(l)}$	$\Delta H = -1410.9kJ$
$2CO_{2(g)} + 3H_2O_{(l)} \rightarrow C_2H_{6(g)} + 7/2\ O_{2(g)})$	$\Delta H = 1559.7kJ$
$H_{2(g)} + ½\ O_{2(g)} \rightarrow H_2O_{(l)}$	$\Delta H = -285.8kJ$

Resulting Equation:
$C_2H_{4(g)} + H_{2(g)} \rightarrow C_2H_{6(g)}$ **$\Delta H = -137.0kJ$**

Standard Enthalpy of Formation

1. Use data from table 6.2 (p257) to calculate ΔH^o for the combustion of butane gas, C_4H_{10}, to produce gaseous carbon dioxide and liquid water.

Answer:
$2C_4H_{10(g)} + 13O_{2(g)} \rightarrow 8CO_{2(g)} + 10H_2O_{(l)}$

Using
$\Delta H^o = \Sigma \nu_p \times \Delta H^o_f(\text{products}) - \Sigma \nu_r \times \Delta H^o_f(\text{reactants})$

$[10(-285.8kJ/mol) + 8(-393.5kJ/mol)] – [2(-125.7kJ/mol) + 13(0kJ/mol)]$
$-6006.0 – (-251.4) =$ **$-5754.6kJ$**

2. The combustion of thiophene, $C_4H_4S_{(l)}$, a compound used in the manufacture of pharmaceuticals, produces carbon dioxide and sulfur dioxide gases and liquid water. The enthalpy change in the combustion of one mole of $C_4H_4S_{(l)}$ is -2523kJ. Use this information and date from Table 6.2 to establish ΔH^o_f for $C_4H_4S_{(l)}$.

Answer:

$C_4H_4S_{(l)} + 6O_{2(g)} \rightarrow 4CO_{2(g)} + SO_{2(g)} + 2H_2O_{(l)}$ $\Delta H = -2523kJ$

$[4(-393.5) + 1(-296.8) + 2(-285.8)] - [1(\Delta H) + 6(0)] = -2523$
$-2442.4 - \Delta H = -2523$
$\Delta H = 80.6kJ/mol$

Ionic Reactions in Solution

Given that $\Delta H^o_f[Mg(OH)_{2(s)}] = -924.5kJ/mol$, what is the standard enthalpy change, ΔH^o, for the reaction of aqueous solutions of magnesium chloride and potassium hydroxide? (Use table 6.3, p 261)

Answer:
$MgCl_{2(aq)} + 2KOH_{(aq)} \rightarrow Mg(OH)_{2(s)} + 2KCl_{(aq)}$

$Mg^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Mg(OH)_{2(s)}$

$[1(-924.5kJ)] - [1(-466.9kJ) + 2(-230.0kJ)]$

$\Delta H^o = 2.4kJ$ per mole of $Mg(OH)_{2(s)}$ formed