Friday worksheet 9 Hess'Law and enthalpy
Name ……

1. Given the following thermochemical equations
   1 -------- $4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(l)$, $\Delta H = -1530 kJmol^{-1}$
   2 -------- $H_2(g) + 1/2O_2(g) \rightarrow H_2O(l)$, $\Delta H = -288\ kJmol^{-1}$
   Calculate the enthalpy of formation of ammonia.
   Reverse equation 1 and multiply by ½.
   $2N_2(g) + 3H_2O(l) \rightarrow 2NH_3(g) + 1½\ O_2(g)\ \Delta H = +765\ kJmol^{-1}$
   Multiply equation 2 by 3
   $3H_2(g) + 1½\ O_2(g) \rightarrow 3H_2O(l),\ \Delta H = -864\ kJmol^{-1}$
   Add the two equations together
   $2N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)\ \Delta H = -99\ kJmol^{-1}$

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2. 1------ $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H = -890\ kJmol^{-1}$
   2------ $CO(g) + 1/2O_2(g) \rightarrow CO_2(g)$ $\Delta H = -284\ kJmol^{-1}$
   3------ $C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -393\ kJmol^{-1}$
   4-------$H_2(g) + 1/2O_2(g) \rightarrow H_2O(l)$ $\Delta H = -286\ kJmol^{-1}$

a) Given the thermochemical equations above write balanced thermochemical equations for the :
   i. formation of methane
      Reverse equation 1

      $CO_2(g) + 2H_2O(l) \rightarrow CH_4(g) + 2O_2(g)$ $\Delta H = +890\ kJmol^{-1}$ -----5
      Multiply equation 4 by 2
      $2H_2(g) + O_2(g) \rightarrow 2H_2O\ (l)$ $\Delta H = -572 kJmol^{-1}$ ------6

      Add equations 5, 6 and 3 to get the equation below
      $C(s) + 2H_2(g) \rightarrow CH_4(g)\ \Delta H = -75 kJmol^{-1}$

   ii. formation of carbon monoxide
      Reverse equation 2
      $CO_2(g) \rightarrow CO(g) + ½\ O_2(g)\ \Delta H = +284 kJmol^{-}$
      Add equation 3 to the equation above to get the equation below
      $C(s) + ½\ O_2(g) \rightarrow CO(g)\ \Delta H = -109 kJmol^{-}$

   iii. combustion of methane in limited oxygen to form carbon monoxide and liquid water.
      Reverse equation 2
      $CO_2(g) \rightarrow CO(g) + ½\ O_2(g)\ \Delta H = +284 kJmol^{-}$
      Add the above equation to equation 1
      $CH_4(g) + 1½\ O_2(g) \rightarrow CO(g) + 2H_2O(l)\ \Delta H = -606 kJmol$

b) Calculate the enthalpy of formation of glucose according to the equation below
$6C(s) + 6H_2(g) + 3O_2(g) \rightarrow C_6H_{12}O_6(s) \Delta H = ?$

Given

$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$ $\Delta H = -1273.3 kJ/mol$

and the equations

1------ $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ ΔH = -890 $kJmol^{-1}$

2------ $CO(g) + 1/2O_2(g) \rightarrow CO_2(g)$ ΔH = -284 $kJmol^{-1}$

3------ $C(s) + O_2(g) \rightarrow CO_2(g)$ ΔH = -393 $kJmol^{-1}$

4-------$H_2(g) + 1/2O_2(g) \rightarrow H_2O(l)$ ΔH = -286 $kJmol^{-1}$

Reverse the combustion of glucose equation above.
$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$ $\Delta H = +1273.3 kJ/mol$
Multiply equations 3 and 4 by 6
$6C(s) + 6O_2(g) \rightarrow 6CO_2(g)$ $\Delta H = -2358 kJ/mol$
$6H_2(g) + 3O_2(g) \rightarrow 6H_2O(l)$ $\Delta H = -1716 kJ/mol$
Now add the three equations together
$6C(s) + 6H_2(g) + 3O_2(g) \rightarrow C_6H_{12}O_6(s)$ ΔH = -2801kJ/mol

3. When ethanol burns in oxygen under standard conditions CO_2 and liquid water are produced.
a. Write a balanced thermochemical equation for the complete combustion of ethanol using information from the Data Booklet .
$C_2H_6O(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ ΔH = -1360kJ/mol
b. Calculate the enthalpy of formation of ethanol given the equations below.
1----------$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ ΔH = -394*kJ/mol*
2----------$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -286 kJ/mol$
Multiply equation 1 by 1.5 and equation 2 by 2
$3H_2(g) + 1½ O_2(g) \rightarrow 3H_2O(l)$ ΔH = -591kJ/mol
$2C(s) + 2O_2(g) \rightarrow 2CO_2(g)$ $\Delta H = -572 kJ/mol$
Reverse the combustion of ethanol equation.
$2CO_2(g) + 3H_2O(l) \rightarrow C_2H_6O(l) + 3O_2(g)$ ΔH = +1360kJ/mol
Now add the three equations
$½ O_2(g) + 3H_2(g) + 2C(s) \rightarrow C_2H_6O(l)$ ΔH = +197kJ/mol

4. *A 5.30 gram sample of pure solid ammonium nitrate is dissolved in 50.0 mL of pure water at 25.0 °C. If the temperature of the water was finally measured at 15.5°C calculate the* ΔH of the equation $NH_4NO_3(s) \rightarrow NH_4^+(aq) + NO_3^-(aq)$ *ΔH = 23kJ/mol*
Step 1 – find the mol of NH_4NO_3
=> 5.30/62.0 = 0.0855 mol
Step 2 – find the mass of water
=> (50.0 X 0.997) = 49.85g
Step 3 – find the amount of energy removed from water
=> E(J) = 4.18 X 49.85 X 9.5 = 1.98 kJ
Step – find the amount of energy removed from the water per mol = 1.98 kJ/0.0855mol =
=> 23kJ/mol (2 sig figs)