

Enthalpies of Formation

Using Hess's Law we can calculate reaction enthalpies for a variety of reactions using tables of known enthalpies

Many experimentally determined enthalpies are listed by the type of process

DH for converting various liquids to the gas phase are listed in tables of enthalpies of vaporization

DH for melting solids to liquids are listed in tables of enthalpies of fusion

DH for for combusting a substance in oxygen are listed in tables of enthalpies of combustion

The enthalpy change associated with the formation of a compound from its constituent elements is called the enthalpy of formation (DH_f)

Conditions which influence enthalpy changes include:

temperature

pressure

state of reactants and products (s, g, l, aq)

The standard state of a substance is the form most stable at 298 °K (25 °C, or standard "room temperature") and 1 atmosphere (1 atm) of pressure

When a reaction occurs with all reactants and products in their standard states, the enthalpy change is the standard enthalpy of reaction (DH°)

Thus, the standard enthalpy of formation (DH°_f) of a compound is the change in enthalpy that accompanies the formation of 1 mole of that substance from its elements, with all substances in their standard states

The standard enthalpy of formation for ethanol (C₂H₅OH) is the enthalpy change for the following reaction

Notes:

Elemental source of oxygen is O₂ and not O because O₂ is the stable form of oxygen at 25 °C and 1 atm, likewise with H₂

Elemental source of carbon is specified as graphite (and not, for example, diamond) because graphite is the lowest energy form of carbon at room temp and 1 atm

Why is the O₂ stoichiometry left at "1/2"? The stoichiometry of formation reactions always indicates the formation of 1 mol of product. Thus, DH°_f values are reported as kJ / mole of the substance produced

If C(graphite) is the lowest energy form of carbon under standard conditions, then what is the DH°_f for C(graphite)?

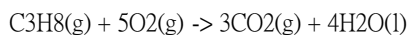
By definition, the standard enthalpy of formation of the most stable form of any element is zero because there is no formation reaction needed when the element is already in its standard state

DH°_f for C(graphite), H₂(g) and O₂(g) = 0

Using enthalpies of formation (DH°_f) to calculate enthalpies of reaction under standard conditions (DH°_{rxn})

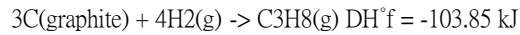
We can determine the standard enthalpy change for any reaction (DH°_{rxn}) by using standard enthalpies of formation (DH°_f) and Hess's Law

Consider the following combustion reaction of propane:

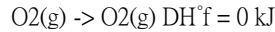


The reactants:

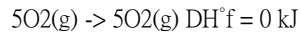
The standard heat of formation (ΔH°_f) of propane gas from its elemental constituents in the standard state is 103.85 kJ/mole



The standard heat of formation (ΔH°_f) for $\text{O}_2(\text{g})$ is zero



and so...



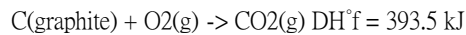
Overall, therefore, the standard heat of formation (ΔH°_f) for the reactants is:



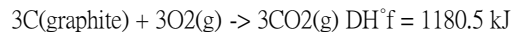
$$\Delta H^\circ_f = -103.85 \text{ kJ}$$

The products:

The standard heat of formation (ΔH°_f) of $\text{CO}_2(\text{g})$ from its elemental constituents in the standard state is 393.5 kJ/mole



so, for 3 moles of CO_2 molecules the standard heat of formation would be:



The standard heat of formation (ΔH°_f) of $\text{H}_2\text{O}(\text{l})$ from its elemental constituents in the standard state is 285.8 kJ/mole

and so the ΔH°_f for 4 waters would be:

combining the ΔH°_f for both products yields:



$$\text{with } \Delta H^\circ_f = (-1180.5) + (-1143.2) = -2323.7 \text{ kJ}$$

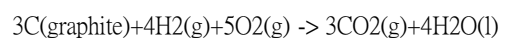
Let's summarize what we have determined so far:

Overall the standard heat of formation (ΔH°_f) for the reactants is:



$$\Delta H^\circ_f = -103.9 \text{ kJ}$$

Overall the standard heat of formation (ΔH°_f) for the products is:



$$\Delta H^\circ_f = -2323.7 \text{ kJ}$$