Standard Reactions of Formation

Since we can't really measure absolute enthalpies (H) and free energies (G), we use an alternative which utilizes state functions that are called standard molar enthalpy (or free energy) of formation. The "of formation" means that the substance (formula) is formed from only the elements in their standard forms. Standard state is 1 bar (or the older standard, 1 atm) and 25°C. Do realize that you can change the standard to some other temperature but you must declare it. ALL tables should include temperature. Assume 25°C (298.15 K) if not explicitly stated. The implied reaction for any formation is the formation of exactly ONE MOLE of the substance from the appropriate amount of moles of elements needed to make that substance. What is the formation reaction for ethanol, C_2H_5OH (liq)?

$$\underbrace{2\,C_{(graphite)} + \tfrac{1}{2}\,O_{2\,(g)} + 3\,H_{2\,(g)}}_{\text{Note how these are only elements and their coefficients adjusted to make exactly 1 mole of product. Fractions for the coefficients are just fine and often necessary as you can see with the oxygen gas above.}} \longrightarrow \underbrace{C_2H_5OH_{\,(liq)}}_{\text{Make sure only ONE mole of product is made.}}$$

That entire reaction has the following values

ΔH = -277.69 kJ/mol $\qquad$ ΔG = -174.78 kJ/mol

We'd rather not have to write all that down each time we want to use ethanol in an equation. The subscript "f" stands for a formation reaction. Once you have formation values for all substances, you can use those in place of he absolute H's and G's and still get the exact same answers. Remember that formation values are explicitly written showing the "f" subscript like you see here.

$\Delta H_f^\circ(C_2H_5OH(\ell))$ = -277.69 kJ/mol $\qquad$ $\Delta G_f^\circ(C_2H_5OH(\ell))$ = -174.78 kJ/mol

Now we can just use ΔH_f° values for any reaction now. We can account for the energies lost and gained when reactants are consumed and products are formed. This leads to the following version of Hess's Law. Realize that the reactions that you are summing up are just formation reactions and all the elements will cancel out of the net overall equation.

$$\Delta H_{rxn}^\circ = \sum n\Delta H_f^\circ(\text{products}) - \sum n\Delta H_f^\circ(\text{reactants})$$

You will get these values from Tables

Because these are state functions, ANY energy related state function will also work a with the same basic formula. Here is the same formula using free energies of formation.

$$\Delta G_{rxn}^\circ = \sum n\Delta G_f^\circ(\text{products}) - \sum n\Delta G_f^\circ(\text{reactants})$$

Similar equations are valid for ΔU and ΔS also. However, ΔU_f° values are never tabulated and neither are ΔS_f° values. You'll find out later that we actually DO have a way to get absolute S values and that is what we will use for entropy.

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