Spontaneous vs. Nonspontaneous

Gibbs free energy measures whether a reaction is spontaneous or not with the equation ΔG = ΔH - TΔS. Thus, based on whether ΔH or ΔS are positive or negative, the reaction may be spontaneous or nonspontaneous at low or high temperatures. It is useful to remember at what temperatures the reaction is spontaneous as written with varying enthalpy and entropy values. If ΔH and ΔS are both negative, the reaction is only spontaneous at low temperatures. This is because at low temperatures the entropy term will be a smaller positive number, making it more likely that the negative enthalpy can drive the spontaneity of the reaction. The opposite is true if ΔH and ΔS are both positive. In this case, a high temperature is needed to make the entropy term a large negative number, because the enthalpy change is positive. If ΔH is negative and ΔS is positive, the reaction is spontaneous at all temperatures because the change in Gibbs free energy is always negative. Contrastingly, if ΔH is positive and ΔS is negative, the reaction is nonspontaneous at all temperatures as written. This is because the change in Gibbs free energy is always positive.

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Spontaneous at Low Temperatures
Spartan in the the Cold
Based on the equation for Gibbs Free Energy, there are certain reactions that are spontaneous at only low temperatures.

ΔH is Negative
Delta-H-Horse Devil
If ΔS, entropy, is negative, and ΔH, enthalpy, is negative, the reaction is spontaneous at low temperatures. Based on the equation ΔG = ΔH - TΔS, we want Gibbs free energy to be negative. This requires a low temperature because a negative change in entropy makes that term positive. If the temperature is high, Gibbs free energy is more likely to be positive.

ΔS is Negative
Delta-S-Snake Devil
If ΔS, entropy, is negative, and ΔH, enthalpy, is negative, the reaction is spontaneous at low temperatures. Based on the equation ΔG = ΔH - TΔS, we want Gibbs free energy to be negative. This requires a low temperature because a negative change in entropy makes that term positive. If the temperature is high, Gibbs free energy is more likely to be positive and the reaction is likely to be nonspontaneous.

Spontaneous at High Temperatures
Spartan in the Heat
Based on the equation for Gibbs Free Energy, there are certain reactions that are spontaneous at only high temperatures.

ΔH is Positive
Delta-H-Horse Angel
If ΔS, entropy, is positive, and ΔH, enthalpy, is positive, the reaction is spontaneous at high temperatures. Based on the equation ΔG = ΔH - TΔS, we want Gibbs free energy to be negative. This requires a high temperature because a positive change in enthalpy makes that term in the equation positive. If the temperature is high. In order for Gibbs free energy to be negative, the entropy term must be greater in magnitude than the enthalpy term, requiring a high temperature.

ΔS is Positive
Delta-S-Snake Angel
If ΔS, entropy, is positive, and ΔH, enthalpy, is positive, the reaction is spontaneous at high temperatures. Based on the equation ΔG = ΔH - TΔS, we want Gibbs free energy to be negative. This requires a high temperature because a positive change in enthalpy makes that term in the equation positive. If the temperature is high. In order for Gibbs free energy to be negative, the entropy term must be greater in magnitude than the enthalpy term, requiring a high temperature.

Spontaneous at All Temperatures
Spartan at All Temperature
Some reactions are spontaneous at all temperatures depending on the values of enthalpy and entropy.

ΔH is Negative

Delta-H-Horse Devil

If ΔS, entropy, is positive, and ΔH, enthalpy, is negative, the reaction is spontaneous at all temperatures. This is because based on the equation ΔG = ΔH - TΔS, Gibbs free energy would always be negative. Thus, the reaction would always be spontaneous.

ΔS is Positive

Delta-S-Snake Angel

If ΔS, entropy, is positive, and ΔH, enthalpy, is negative, the reaction is spontaneous at all temperatures. This is because based on the equation ΔG = ΔH - TΔS, Gibbs free energy would always be negative. Thus, the reaction would always be spontaneous.

Nonspontaneous at All Temperatures

Nun-Spartan at All Temperatures

Some reactions will never be spontaneous as written based on the changes in entropy and enthalpy associated with them.

ΔH is Positive

Delta-H-Horse Angel

If ΔS, entropy, is negative, and ΔH, enthalpy, is positive, the reaction isnon spontaneous at all temperatures. This is because based on the equation ΔG = ΔH - TΔS, Gibbs free energy would always be positive and can never be negative. Thus, the reaction would always be nonspontaneous.

ΔS is Negative

Delta-S-Snake Devil

If ΔS, entropy, is negative, and ΔH, enthalpy, is positive, the reaction isnon spontaneous at all temperatures. This is because based on the equation ΔG = ΔH - TΔS, Gibbs free energy would always be positive and can never be negative. Thus, the reaction would always be nonspontaneous.