Thermodynamics and Free Energy

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a. **What exactly is Gibbs Free Energy?**

Gibbs Free Energy (G) - The energy associated with a chemical reaction that can be used to do work. The free energy of a system is the sum of its enthalpy (H) plus the product of the temperature (Kelvin) and the entropy (S) of the system: Free energy of reaction.

b.Why Gibbs Free Energy is called Free Energy?

Gibbs free energy is a measure of the amount of energy available to do work in an isothermal and isobaric (constant temperature and pressure) thermodynamic system. This is where the term "free" comes from; it refers to the amount of energy in a system that is easily available for usage.

c.What is the difference between Gibbs Free Energy and Enthalpy?

Enthalpy and Gibbs Free Energy indicate different things. Enthalpy can tell you about the relative stabilities of the products and reactants. Gibbs free energy however can tell you about whether a reaction is spontaneous (whether a reaction will occur) under a set of specified conditions.

d.Why do we use Gibbs Energy?

Gibbs free energy and spontaneity. How the second law of thermodynamics helps us determine whether a process will be spontaneous, and using changes in Gibbs free energy to predict whether a reaction will be spontaneous in the forward or reverse direction (or whether it is at equilibrium!).

e.What are the three laws of Thermodynamics?

The first law, also known as Law of Conservation of Energy, states that energy cannot be created or destroyed in an isolated system. ... The third law of thermodynamics states that the entropy of a system approaches a constant value as the temperature approaches absolute zero.

f. Who wrote the three laws of Thermodynamics?

By 1860, as formalized in the works of those such as Rudolf Clausius and William Thomson, two established principles of thermodynamics had evolved, the first principle and the second principle, later restated as thermodynamic laws.

g. Are there 3 or 4 Laws of Thermodynamics?

The 4 Laws

Zeroth law of thermodynamics – If two thermodynamic systems are each in thermal equilibrium with a third, then they are in thermal equilibrium with each other. First law of thermodynamics – Energy can neither be created nor destroyed. It can only change forms.

h. What are the three types of system?

There are three mains types of system: open system, closed system and isolated system.

Problems

1. Calculate the Gibbs free energy change (ΔG) for the following chemical reaction:
ATP ADP + P_i
The reaction occurs at 68 °F, the change in heat (ΔH) = 19,070 cal, and the change in entropy (ΔS) = 90 cal/K.
68 °F = 293 K, therefore the equation is set up in the following way:
$\Delta G = \Delta H - T\Delta S$
$\Delta G = 19{,}070\ cal - (293\ K)\ (90\ cal/K)$
$\Delta G = -7300\ cal = -7.3\ kcal$
2. Calculate the Gibbs free energy change (ΔG) for the following chemical reaction:

glutamate + NH_3 glutamine + H_2O
The reaction occurs at 68 °F, the change in heat (ΔH) = 4103 cal, and the change in entropy (ΔS) = 2.4 cal/K.
68 °F = 293 K, therefore the equation is set up in the following way:
$\Delta G = \Delta H - T\Delta S$
$\Delta G = 4103\ cal - 293\ K\ (2.4\ cal/\ K)$
$\Delta G = 3399.8\ cal = 3.4\ kcal$
3. Would either of the reactions above occur spontaneously? If so, which one(s) and why?

The reaction with ATP in #1. The change in Gibbs free energy (ΔG) is negative for exothermic reactions and can only be negative for spontaneous reactions. However, the activation energy required would still cause this reaction to occur slowly.
4. Are either of the above reactions endergonic? If so, which one(s) and why?

The reaction with glutamate and NH_3 in #2. The change in ΔG (free energy) is positive, meaning free energy is absorbed, making this reaction endergonic.

5. How does the Gibbs free energy in each of the two reactions change if the temperature were raised to normal body temperature (98.6 °F)?
98.6 °F = 310 K. Changing the equations accordingly looks like this:
#1
$\Delta G = \Delta H - T\Delta S$
$\Delta G = 19{,}070\ cal - (310\ K)\ (90\ cal/K)$
$\Delta G = -8830\ cal = -8.83\ kcal$
#2
$\Delta G = \Delta H - T\Delta S$
$\Delta G = 4103\ cal - 310\ K\ (2.4\ cal/\ K)$
$\Delta G = 3359\ cal = 3.359\ kcal$

6. Does an increase in reaction temperature make each of these reactions more or less likely to occur spontaneously? Explain your answer.

#1
This reaction now becomes more exothermic and is likely to occur faster/more spontaneously. Although activation energy remains a hurdle, the entropy of the products is dramatically higher, making this reaction more thermodynamically favorable.
#2
This reaction now becomes less endothermic and requires less energy input to occur. While this is more thermodynamically favorable, the free energy change is still positive, meaning this reaction will still not occur spontaneously.