Spontaneity, Entropy, and Free Energy
Part III

It's time to start putting themes and topics together in our homework and in our tests. You will start to get an idea about the type of comprehensive questioning you can expect to see on the AP exam in May. So get out your old notes and let's get to it!

1. $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ $\Delta H^o = -114.1$ kJ, $\Delta S^o = -146.5$ J/K

The reaction represented above is one that contributes significantly to the formation of photochemical smog.

(a) Calculate the quantity of heat released when 73.1 g of NO(g) is converted to $NO_2(g)$.

(b) For the reaction at 25 °C, the value of the standard free-energy change, ΔG^o, is –70.4 kJ.

(i) Calculate the value of the equilibrium constant, K_{eq}, for the reaction at 25 °C.

(ii) Indicate whether the value of ΔG would become more negative, less negative, or remain unchanged as the temperature is increased. Justify your answer.

(c) Use the data below to calculate the value of the standard molar entropy, S^o, for $O_2(g)$ at 25 °C.

Compound	Standard Molar Entropy, S^o (J/mol K)
NO(g)	210.8
$NO_2(g)$	240.1

(d) Use the data in the table below to calculate the bond energy, in kJ/mol, of the nitrogen-oxygen bond in NO_2. Assume that the bonds in the NO_2 molecule are equivalent (i.e., they have the same energy).

Bond	Bond Energy (kJ/mol)
Nitrogen-oxygen bond in NO	607
Oxygen-oxygen bond in O_2	495
Nitrogen-oxygen bond in NO_2	?

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2. $C_2H_2(g) + 2H_2(g) \rightarrow C_2H_6(g)$

Substance	S^o (J/mol K)	ΔH^o_f (kJ/mol)	Bond	Bond Energy (kJ/mol)
$C_2H_2(g)$	200.9	226.7	C-C	347
			C=C	611
$H_2(g)$	130.7	0	H-H	436
$C_2H_6(g)$	------	-84.7	C-H	414

(a) If the value of the entropy change, ΔS^o, for the reaction is –232.7 joules per mole Kelvin, calculate the standard molar entropy, S^o, of C_2H_6 gas.

(b) Calculate the value of the standard free-energy constant, ΔG^o, for the reaction. What does the sign of ΔG^o indicate about the reaction above?

(c) Calculate the value of the equilibrium constant, K, for the above reaction at 298 K.

(d) Calculate the value of the C [triple bond] C bond energy in C_2H_2 in kilojoules per mole.

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3. $2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$

The reaction represented above is spontaneous at 25° C. Assume that all reactants and products are in their standard states.

(a) Predict the sign of ΔS^o for the reaction and justify your prediction.

(b) What is the sign of ΔG^o for the reaction? How would the sign and magnitude of ΔG^o be affected by an increase in temperature to 50° C? Explain your answer.

(c) What must be the sign of ΔH^o for the reaction at 25 °C? How does the total bond energy of the reactants compare to that of the products?

(d) When the reactants are placed together in a container, no change is observed even though the reaction is known to be spontaneous. Explain this observation.