3.8.1: Biology- Weight of Food and Energy Production

As we've seen, the diet of Eagles (along with all other animals including us) includes certain masses of food. For eagles, it's 250-550 g/day. We also saw that this provides the energy for all the day's activities, and food that's left after energy production goes to weight gain. How is the mass of food related to the energy produced? The first step in answering this question is as simple one, and involves writing an overall "thermochemical equation" for the metabolism of sugar, which turns out to be the same as the equation for the combustion of sugar. A thorough answer to this question requires us to consider other factors, which we'll take up later.

Thermochemical equations are used to relate energy changes to the chemical reactions that produce them. For example, we've already seen in Metabolism of Dietary Sugar that sugar is metabolized according to the equation[1]:

$C_6H_{12}O_6(s) + 6\ O_2(g) \rightarrow 6\ CO_2(g) + 6\ H_2O(l)$ (25º, 1 Atm) ΔH_m = –2808 kJ (1) Here the sign of ΔH_m (delta *H* subscript m) tells us whether heat energy is released or absorbed when the reaction occurs and the value enables us to find the actual quantity of energy involved. By convention, if ΔH_m is *positive*, heat is *absorbed* by the reaction; i.e., it is endothermic. More commonly, ΔH_m is *negative* as in Eq. (1), indicating that heat energy is *released* rather than absorbed by the reaction, and that the reaction is **exothermic**. This convention as to whether ΔH_m is positive or negative looks at the heat change in terms of the matter actually involved in the reaction rather than its surroundings. In the reaction in Eq. (1), the C, H, and O atoms have collectively lost energy and it is this loss which is indicated by a negative value of ΔH_m.

It is important to notice that ΔH_m is the energy change for the equation as written. This is necessary because the quantity of heat released or absorbed by a reaction is proportional to the amount of each substance consumed or produced by the reaction. Thus Eq. (1) tells us that 2805 kJ of heat energy is given off *for every mole of $C_6H_{12}O_6$ which is consumed. Alternatively, it tells us that 2808 kJ is released* for every 6 mole of *H_2O produced, i.e., 468 kJ is produced for every mol H_2O.* ΔH_m for Equation (1) also tells us that 2808 kJ of heat is released when 6 mol of carbon dioxide is produced, or 6 mol of oxygen is consumed. Seen in this way, ΔH_m is a conversion factor enabling us to calculate the heat absorbed when a given amount of substance is consumed or produced. If q *is the quantity of heat absorbed and* n *is the amount of substance involved, then*

$\Delta H_\mathrm{m} = \frac{q}{n}$ (2)

EXAMPLE 1 How much heat energy is obtained if we assume that the eagle's diet of 250-550 g includes 350 g of glucose, $C_6H_{12}O_6$, which is burned in oxygen according to the equation:

$C_6H_{12}O_6(s) + 6\ O_2(g) \rightarrow 6\ CO_2(g) + 6\ H_2O(l)$

ΔH_m = –2808 kJ (3)

Solution

The mass of $C_6H_{12}O_6$ is easily converted to the amount of $C_6H_{12}O_6$ from which the heat energy *q* is easily calculated by means of Eq. (2). The value of ΔH_m is –2805 kJ per mole of $C_6H_{12}O_6$,

$m_{\mathrm{C_6H_{12}O_6}} \xrightarrow{M} n_{\mathrm{C_6H_{12}O_6}} \xrightarrow{\Delta H_m} q$

so that

$q = 350\text{ g C}_6\text{H}_{12}\text{O}_6 \times \frac{1\text{ mol C}_6\text{H}_{12}\text{O}_6}{180.16\text{ g C}_6\text{H}_{12}\text{O}_6} \times \frac{-2808\text{ kJ}}{\text{mol C}_6\text{H}_{12}\text{O}_6} = -5\ 455\text{ kJ}$ Note: By convention a negative value of *q* corresponds to a release of heat energy by the matter involved in the reaction. The quantity ΔH_m is the **enthalpy change for the reaction equation as written**. In this context the symbol Δ (delta) signifies change in" while *H* is the symbol for the quantity being changed, namely the enthalpy. We will deal with the enthalpy in some detail in Enthalpy For the moment we can think of it as a property of matter which increases when matter absorbs energy and decreases when matter releases energy.

It is important to realize that the value of ΔH_m given in thermochemical equations like (1) or (3) depends on the physical state of both the reactants and the products. Thus, if water were obtained as a gas instead of a liquid in the reaction in Eq. (1), the value of ΔH_m would be different from -2808 kJ. It is also necessary to specify both the temperature and pressure since the value of ΔH_m depends very slightly on these variables. If these are not specified [as in Eq. (3)] they usually refer to 25°C and to normal atmospheric pressure.

Two more characteristics of thermochemical equations arise from the law of conservation of energy. The first is that *writing an equation in the reverse direction changes the sign of the enthalpy change.* For example,

$H_2O(l) \rightarrow H_2O(g)$ ΔH_m = 44 kJ (4*a*) tells us that when a mole of liquid water vaporizes, 44 kJ of heat is absorbed. This corresponds to the fact that heat is absorbed from your skin when perspiration evaporates, and you cool off. Condensation of 1 mol of water vapor, on the other hand, gives off exactly the same quantity of heat. $H_2O(g) \rightarrow H_2O(l)$ ΔH_m = –44 kJ (4*b*) To see why this must be true, suppose that ΔH_m [Eq. (4a)] = 44 kJ while ΔH_m [Eq. (4b)] = –50.0 kJ. If we took 1 mol of liquid water and allowed it to evaporate, 44 kJ would be absorbed. We could then condense the water vapor, and 50.0 kJ would be given off. We could again have 1 mol of liquid water at 25°C but we would also have 6 kJ of heat which had been created from nowhere! This would violate the law of conservation of energy. The only way the problem can he avoided is for ΔH_m of the reverse reaction to be equal in magnitude but opposite in sign from ΔH_m of the forward reaction. That is, ΔH_m forward = –ΔH_m reverse

References

1. Atkins, P. Physical Chemistry, 6th Ed., W.H. Freeman &Co. New York, 1998, p. 69

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