The heat generated during microbial growth can be calculated using the heat of combustion of the substrate and of cellular material. A schematic of an enthalpy balance for microbial utilization of substrate is presented in Fig. 6.10. The heat of combustion of the substrate is equal to the sum of the metabolic heat and the heat of combustion of the cellular material.

$$\frac{\Delta H_s}{Y_{X/S}} = \Delta H_c + \frac{1}{Y_H} \tag{6.27a}$$

where ΔH_s is the heat of combustion of the substrate (kJ/g substrate), $Y_{X/S}$ is the substrate yield coefficient (g cell/g substrate), ΔH_c is the heat of combustion of cells (kJ/g cells), and $1/Y_H$ is the metabolic heat evolved per gram of cell mass produced (kJ/g cells).

Equation 6.27a can be rearranged to yield

$$Y_H = \frac{Y_{X/S}}{\Delta H_s - Y_{X/S}\,\Delta H_c} \tag{6.27b}$$

ΔH_s and ΔH_c can be determined from the combustion of substrate and cells. Typical ΔH_c values for bacterial cells are 20 to 25 kJ/g cells. Typical values of Y_H are glucose, 0.42 g/kcal; malate, 0.30 g/kcal; acetate, 0.21 g/kcal; ethanol, 0.18 g/kcal; methanol, 0.12 g/kcal; and methane, 0.061 g/kcal. Clearly, the degree of oxidation of the substrate has a strong effect on the amount of heat released.

The total rate of heat evolution in a batch fermentation is

$$Q_{GR} = V_L \mu_{\text{net}} X \frac{1}{Y_H} \tag{6.28}$$

where V_L is the liquid volume (l) and X is the cell concentration (g/l).

In aerobic fermentations, the rate of metabolic heat evolution can roughly be correlated to the rate of oxygen uptake, since oxygen is the final electron acceptor.

$$Q_{GR} \cong 0.12 Q_{O_2} \tag{6.29}$$

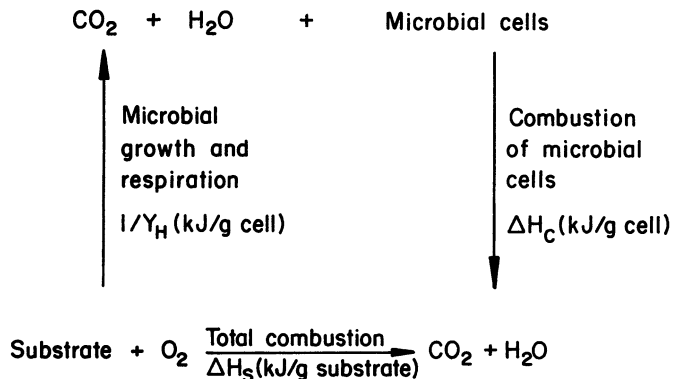

Figure 6.10. Heat balance on microbial utilization of substrate.