where CH_mO_n represents 1 mole of carbohydrate and $CH_\alpha O_\beta N_\delta$ stands for 1 mole of cellular material. Simple elemental balances on C, H, O, and N yield the following equations:

$$\begin{aligned} &\text{C:} \quad 1 = c + e \\ &\text{H:} \quad m + 3b = c\alpha + 2d \\ &\text{O:} \quad n + 2a = c\beta + d + 2e \\ &\text{N:} \quad b = c\delta \end{aligned} \tag{7.4}$$

The respiratory quotient (RQ) is

$$\mathrm{RQ} = \frac{e}{a} \tag{7.5}$$

Equations 7.4 and 7.5 constitute five equations for five unknowns a, b, c, d, and e. With a measured value of RQ, these equations can be solved to determine the stoichiometric coefficients.

7.3.2. Degree of Reduction

In more complex reactions, as in the formation of extracellular products, an additional stoichiometric coefficient is added, requiring more information. Also, elemental balances provide no insight into the energetics of a reaction. Consequently, the concept of *degree of reduction* has been developed and used for proton–electron balances in bioreactions. The degree of reduction, γ, for organic compounds may be defined as the number of equivalents of available electrons per gram atom C. The available electrons are those that would be transferred to oxygen upon oxidation of a compound to CO_2, H_2O, and NH_3. The degrees of reduction for some key elements are C = 4, H = 1, N = −3, O = −2, P = 5, and S = 6. The degree of reduction of any element in a compound is equal to the valence of this element. For example, 4 is the valence of carbon in CO_2 and −3 is the valence of N in NH_3. Degrees of reduction for various organic compounds are given in Table 7.4. The following are examples of how to calculate the degree of reduction for substrates.

Methane (CH_4): $1(4) + 4(1) = 8, \quad \gamma = 8/1 = 8$

Glucose ($C_6H_{12}O_6$): $6(4) + 12(1) + 6(-2) = 24, \quad \gamma = 24/6 = 4$

Ethanol (C_2H_5OH): $2(4) + 6(1) + 1(-2) = 12, \quad \gamma = 12/2 = 6$

A high degree of reduction indicates a low degree of oxidation. That is, $\gamma_{CH_4} > \gamma_{EtOH} > \gamma_{glucose}$.

Consider the aerobic production of a single extracellular product.

$$\underset{\text{substrate}}{CH_mO_n} + aO_2 + bNH_3 \longrightarrow c\underset{\text{biomass}}{CH_\alpha O_\beta N_\delta} + d\underset{\text{product}}{CH_xO_yN_z} + eH_2O + f\,CO_2 \tag{7.6}$$

The degrees of reduction of substrate, biomass, and product are

$$\gamma_s = 4 + m - 2n \tag{7.7}$$