while for CO_2 the maximum yield is

$$Y_{CO_2/S} = \frac{2(44)}{180} = 0.49 \text{ g ethanol/g glucose}$$

In practice, these maximal yields are not obtained. The product yields are about 90% to 95% of the maximal values, because the glucose is converted into biomass and other metabolic by-products (e.g., glycerol or acetate).

7.5. SUMMARY

Simple methods to determine the reaction stoichiometry for bioreactors are reviewed. These methods lead to the possibility of predicting yield coefficients for various fermentations using a variety of substrates. By coupling these equations to experimentally measurable parameters, such as the respiratory quotient, we can infer a great deal about the progress of a fermentation. Such calculations can also assist in initial process design equations by allowing the prediction of the amount of oxygen required (and consequently heat generated) for a certain conversion of a particular substrate. The prediction of yield coefficients is not exact, because unknown or unaccounted for metabolic pathways and products are present. Nonetheless, such calculations provide useful first estimates of such parameters.

SUGGESTIONS FOR FURTHER READING

ATKINSON, B., AND F. MAVITUNA, *Biochemical Engineering and Biotechnology Handbook*, Macmillan, Inc., New York, 1983.

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ERICKSON, L. E., AND D. Y.-C. FUNG, *Handbook on Anerobic Fermentations*, Marcel Dekker, Inc., New York, 1988. (Five chapters deal with bioenergetics, stoichiometry, and yields.)

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MINKEVICH, I. G., Mass and Energy Balance for Microbial Product Synthesis: Biochemical and Cultural Aspects, *Biotechnol. Bioeng. 25*:1267, 1983.

ROELS, J. A., *Energetics and Kinetics in Biotechnology*, Elsevier Science Publishing, New York, 1983.

PROBLEMS

7.1. Determine the amount of $(NH_4)_2SO_4$ to be supplied in a fermentation medium where the final cell concentration is 30 g/l in a 10^3 l culture volume. Assume that the cells are 12% nitrogen by weight and $(NH_4)_2SO_4$ is the only nitrogen source.