FDE 307
Mass Transfer and Unit Operations

CONVECTIVE MASS TRANSFER

Example:

A sphere of naphthalene was hung up in the air at 45°C and 1 atm abs flowing at a velocity of 0.305 m/s. The diameter of the sphere is 25.4 mm. The diffusivity of naphthalene in air at 45°C is 6.92×10^{-6} m^2/s and the vapour pressure of solid naphthalene is 0.555 mmHg. Calculate the flux for mass transfer from a sphere of naphthalene to air and the value of the mass transfer coefficient.

Example:

A large volume of pure water at 26.1 C is flowing parallel to a flat plate of solid acetic acid, where L=0.244 m in the direction of flow. The water velocity is 0.061 m/s. The solubility of acetic acid in water is 0.02948 kgmol/m3. The diffusivity of acetic acid is 1.245×10^{-6} m^2/s. Calculate the mass transfer coefficient k_L and the flux N_A

UNSTEADY STATE MASS TRANSFER

- Up to now, we have focused on the steady-state mass transfer where the concentration at a given point was constant with time. In this chapter, we shall consider cases where the concentration varies with time, thus resulting in unsteady-state molecular diffusion or transient diffusion. Unsteady-state diffusion can be categorized as; a process that is in an unsteady-state only during its initial startup, and a process in which the concentration is continually changing throughout its duration.

- Convenient charts (Heissler charts) for various geometries as in unsteady-state heat transfer can be used.
- In order to use these charts for solving unsteady state diffusion problems, the dimensionless variables or parameters for heat transfer must be related to those for mass transfer. The conversions of these variables are given in Table 7.1.1

$$N_A = k_c(C_{L1} - C_{Li})$$

where k_c is a mass transfer coefficient in m/s, C_{L1} is the bulk fluid concentration in kgmol A/m^3, C_{Li} is the concentration of the fluid just adjacent to the surface of the solid in kgmol A/m^3.

- K (Equilibrium distribution coefficient)

- One should note that the initial concentration in the solid, c_i, is in equilibrium with C_{Li}. This equilibrium can be abbreviated by a constant called equilibrium distribution coefficient, K, and calculated as the following;

$$K = \frac{C_{Li}}{C_i}$$

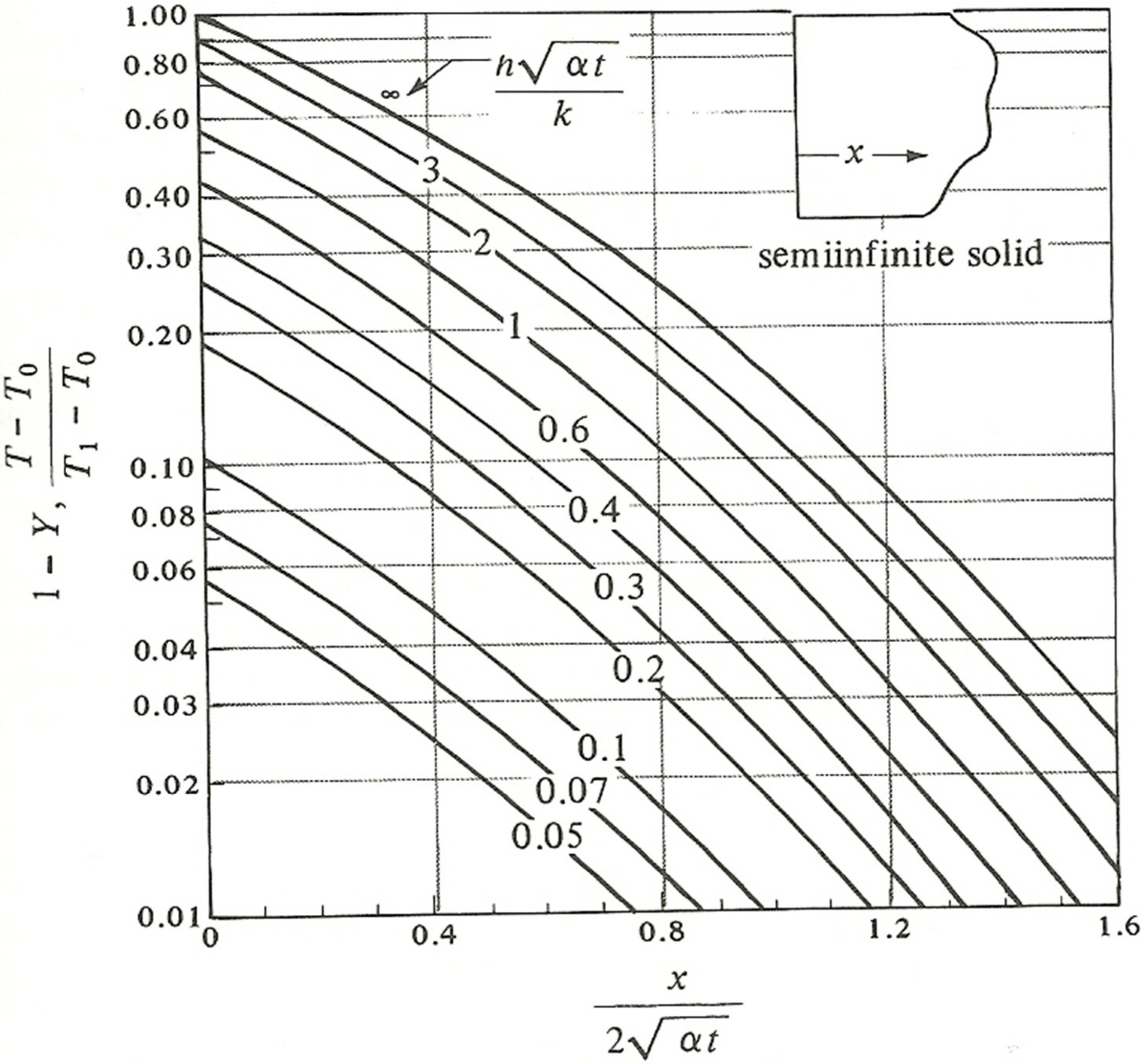

FIGURE 5.3-3. *Unsteady-state heat conducted in a semiinfinite solid with surface convection. Calculated from Eq. (5.3-7)(SI).*

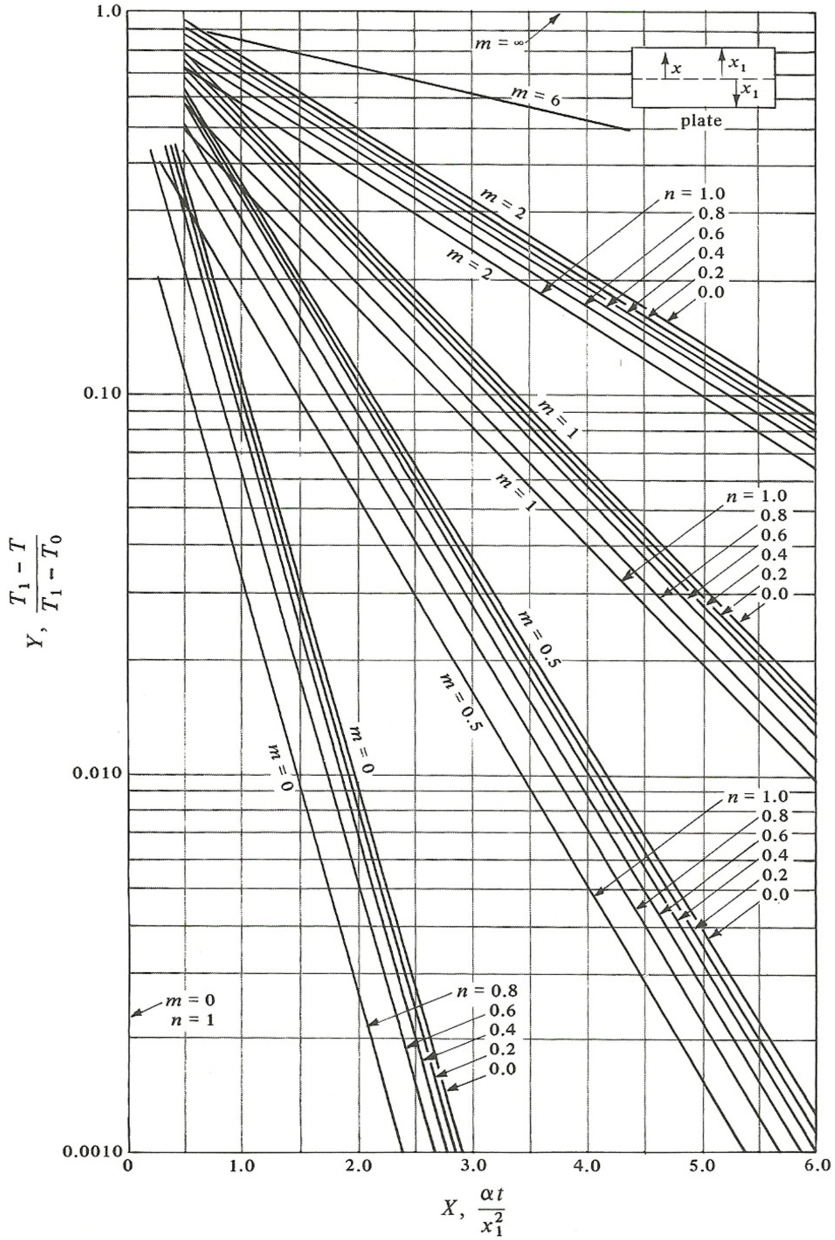

FIGURE 5.3-5. *Unsteady-state heat conduction in a large flat plate.* [*From H. P. Gurney and J. Lurie, Ind. Eng. Chem.,* **15**, *1170* (*1923*).]

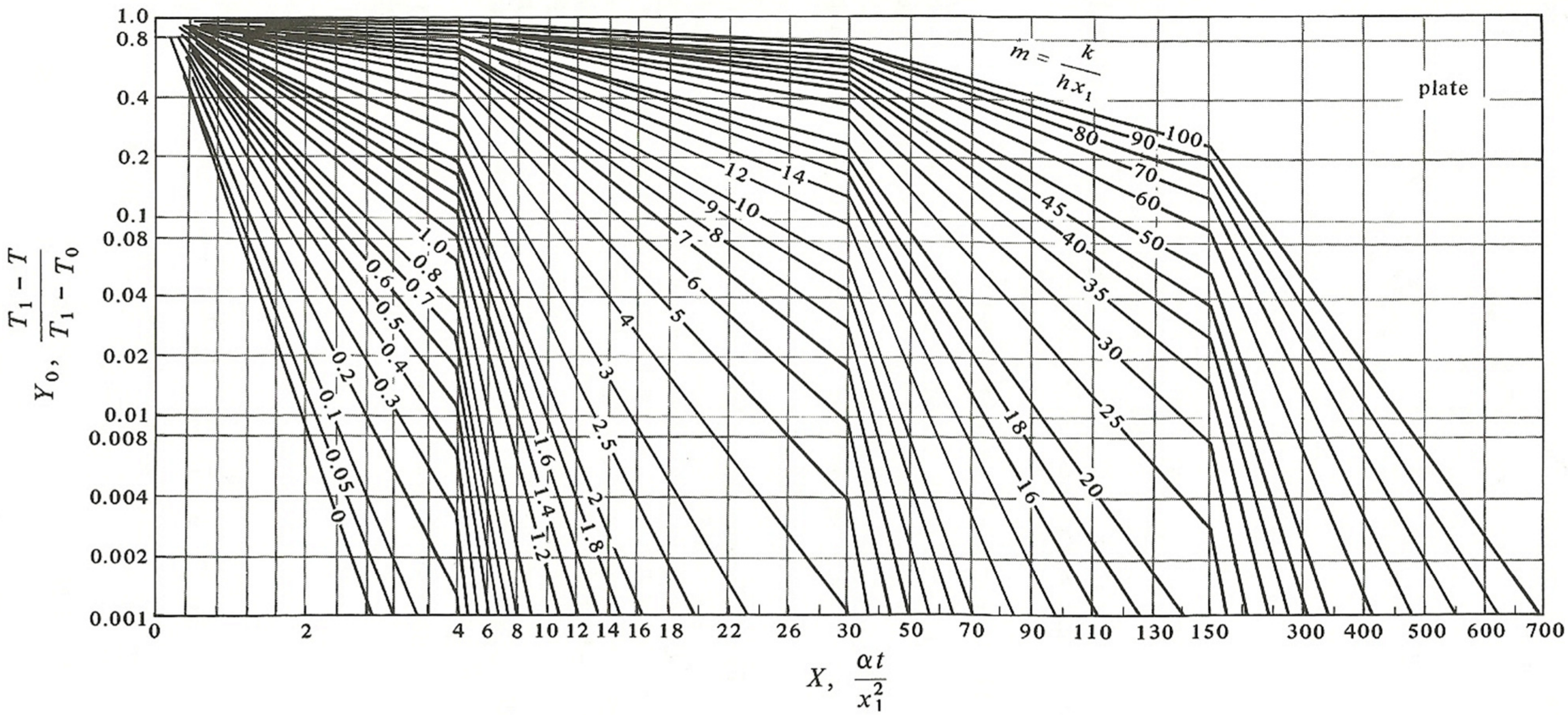

FIGURE 5.3-6. *Chart for determining temperature at the center of a large flat plate for unsteady-state heat conduction. [From H. P. Heisler, Trans. A.S.M.E.,* **69**, *227 (1947). With permission.]*

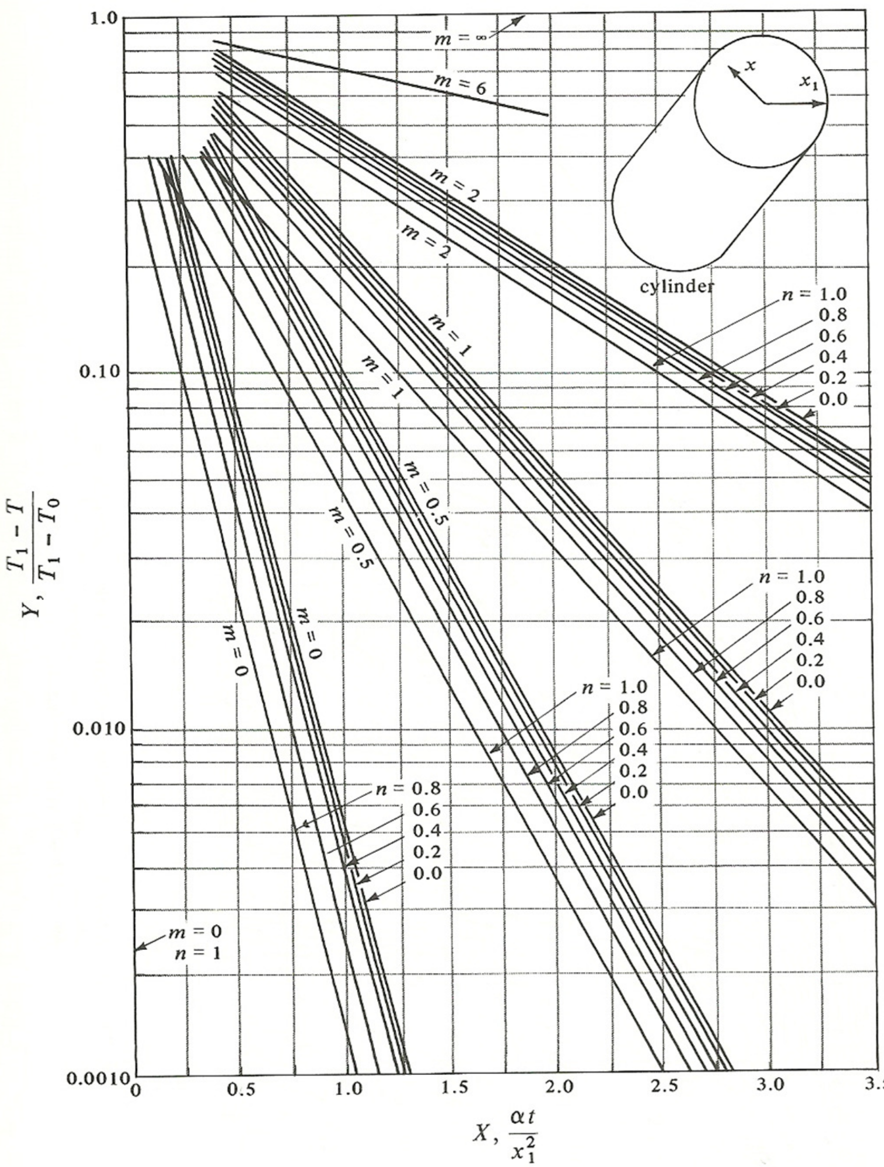

FIGURE 5.3-7. *Unsteady-state heat conduction in a long cylinder.* [*From H. P. Gurney and J. Lurie, Ind. Eng. Chem.*, **15**, *1170* (*1923*).]

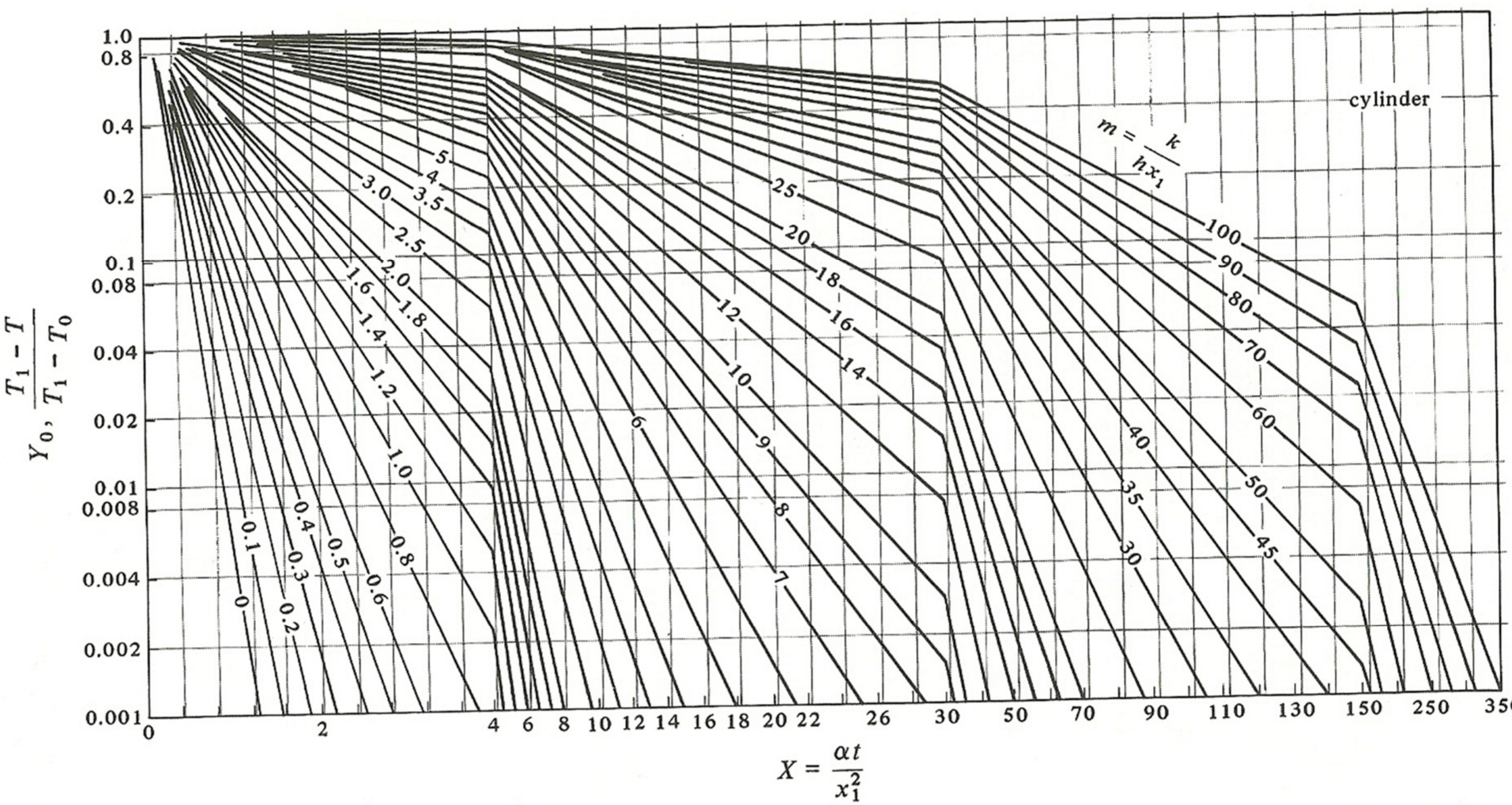

FIGURE 5.3-8. *Chart for determining temperature at the center of a long cylinder for unsteady-state heat conduction. [From H. P. Heisler, Trans. A.S.M.E.,* **69**, *227 (1947). With permission.]*

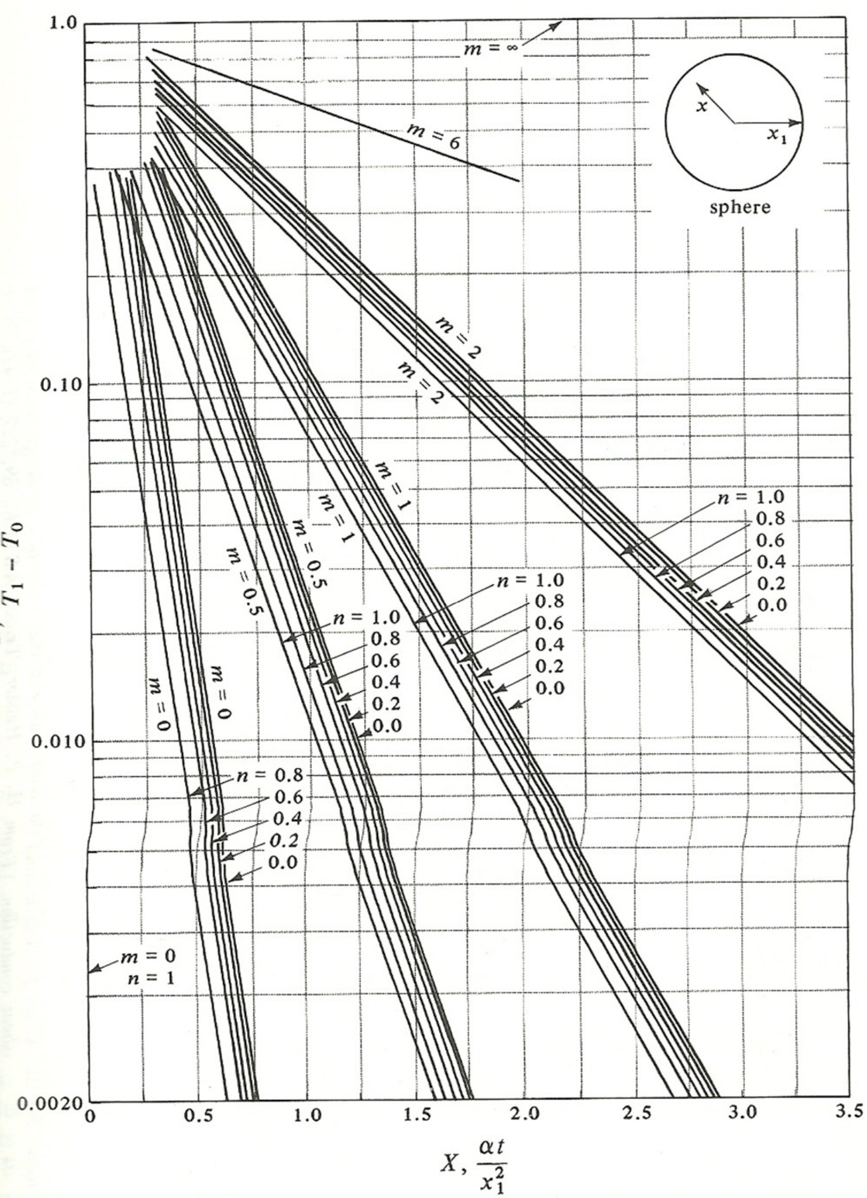

FIGURE 5.3-9. *Unsteady-state heat conduction in a sphere.* [*From H. P. Gurney and J. Lurie, Ind. Eng. Chem.*, **15**, *1170* (*1923*).]

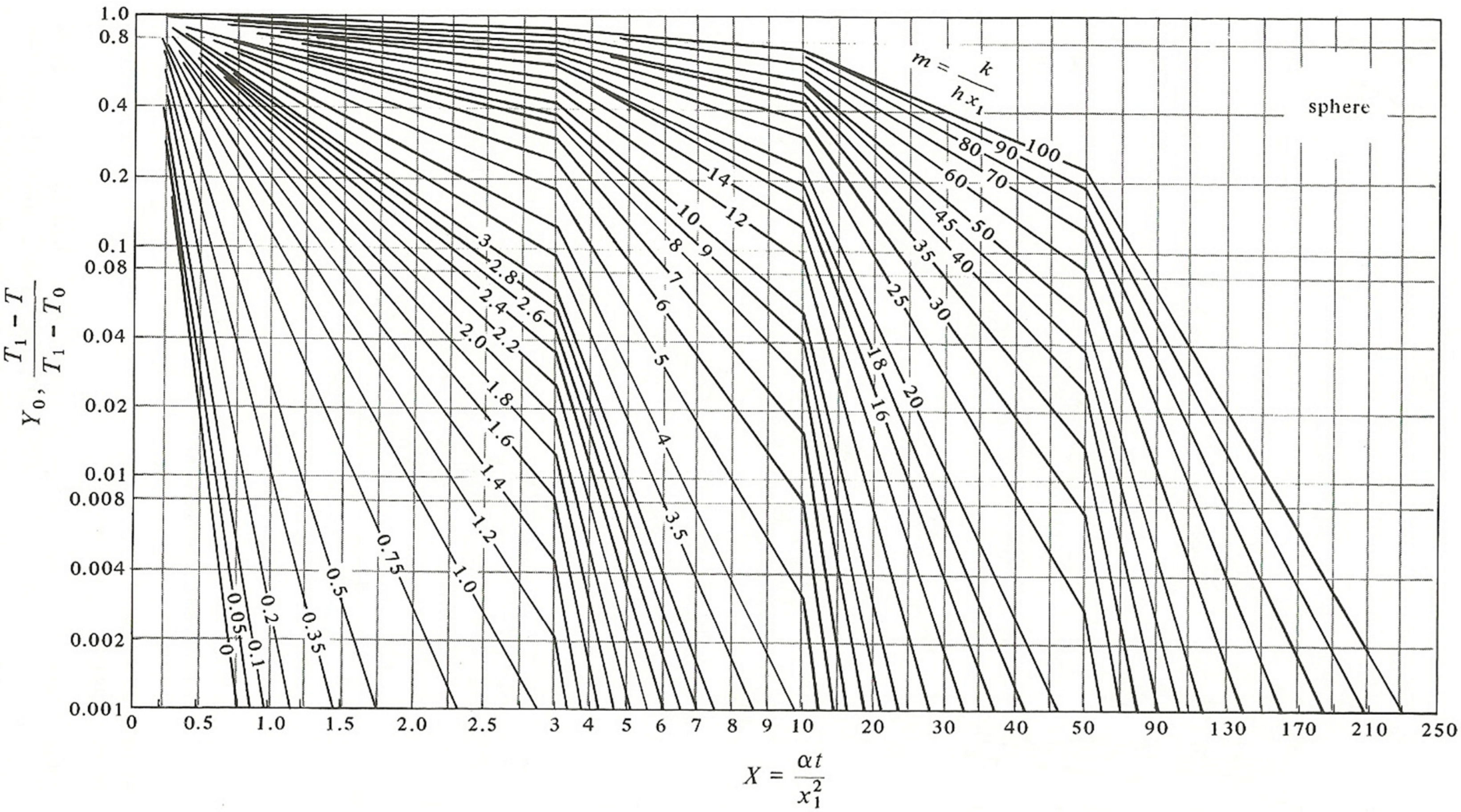

FIGURE 5.3-10. *Chart for determining the temperature at the center of a sphere for unsteady-state heat conduction.* [*From H. P. Heisler, Trans. A.S.M.E.,* **69**, *227 (1947). With permission.*]

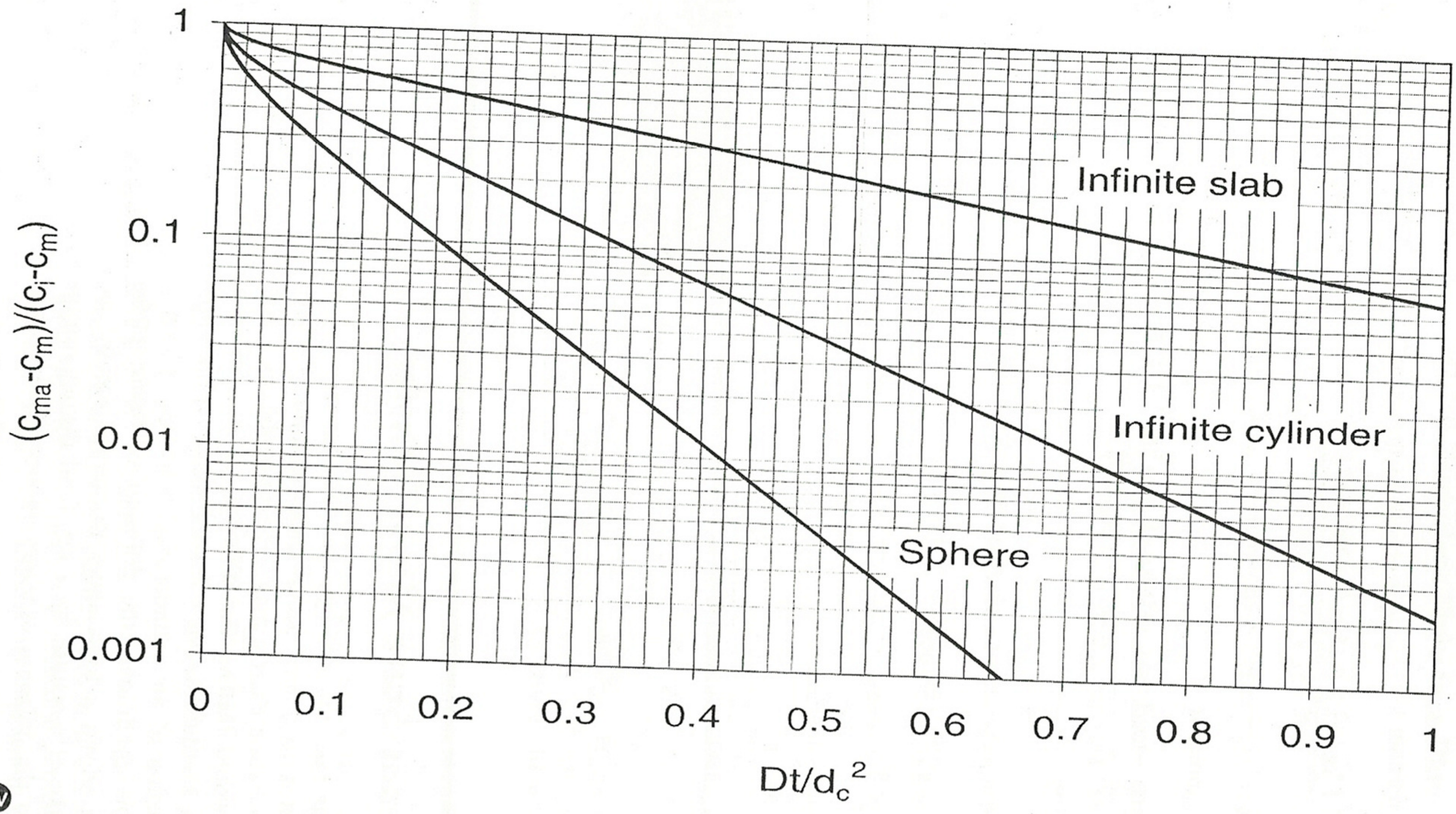

Figure 10.3 Unsteady-state mass transfer chart for mass average concentration in three standard geometries. (From Treybal, 1968.)

Unsteady state diffusion in multidimensional systems

- We have discussed one dimensional systems up to now. For the multidimensional systems, overall solution for the simultaneous diffusion can be obtained by multiplying the solutions for each direction as we have discussed in Heat Transfer course.

$$Y_{x,y,z} = Y_x Y_y Y_z = \frac{c_1 / K - c_{x,y,z}}{c_1 / K - c_0}$$

Example

A piece of banana with a thickness of 1 cm and radius of 2 cm is dried from both sides. The initial moisture content of banana is 73 % (w/w). The equilibrium moisture content at the surface of the sample due to the drying air blown over it is held at 5 % (w/w). The diffusivity of the drying process can be assumed as $3.72\ 10^{-11}\ m^2/s$. The convective mass transfer coefficient can be taken as $9.56\ 10^{-4}\ m/s$. Calculate the time for the center to reach 8 % (w/w) moisture.