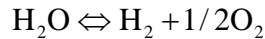


## ChE 400 Applied Chemical Engineering Calculations

### Roots of equations: Proposed Problems

**1. Chemical equilibrium.** In a process water vapor ( $\text{H}_2\text{O}$ ) is heated to sufficiently high temperatures that a significant portion of the water dissociates, or splits apart, to form oxygen and hydrogen:



If it is assumed that this is the only reaction involved, the mole fraction  $x$  of  $\text{H}_2\text{O}$  that dissociates can be represented by

$$K = \frac{x}{1-x} \sqrt{\frac{2P_t}{2+x}}$$

where  $K$  is the reaction's equilibrium constant and  $P_t$  is the total pressure of the mixture. If  $P_t = 3$  and  $K = 0.05$ , determine the value of  $x$ . Solve the problem developing a spread sheet that uses the Newton Raphson method. Compare your solution with the ones obtained by using goal seek (excel) and fsolve (Matlab).

**2. Volume of liquid in a cylindrical tank.** The volume of liquid  $V$  in a hollow horizontal cylinder of radius  $r$  and length  $L$  is related to the depth of the liquid  $h$  by:

$$V = \left[ r^2 \cos^{-1} \left( \frac{r-h}{r} \right) - (r-h) \sqrt{2rh - h^2} \right] L$$

Develop a spread sheet in excel that uses the secant method to determine  $h$  given  $r = 2$  m,  $L = 5$  m<sup>3</sup> and  $V = 8$  m<sup>3</sup>. Compare your solution with the ones obtained by using goal seek (excel) and fsolve (Matlab).

**3. Terminal velocity of a solid particle.** The terminal velocity of a solid spherical particle falling in fluid media can be expressed by the equation

$$v_t = \sqrt{\frac{4g(\rho_p - \rho)D_p}{3C_D\rho}}$$

where:

$v_t$ : terminal velocity (m/s)

$g$ : gravitational constant (m/s<sup>2</sup>)

$\rho_p$ : particle's density (kg/m<sup>3</sup>)

$\rho$ : density of the fluid (kg/m<sup>3</sup>)

$D_p$ : diameter of a spherical particle (m)

$C_D$ : dimensionless drag coefficient

The drag coefficient varies with the Reynolds number (Re) as:

$$C_D = \frac{24}{\text{Re}} \text{ for } \text{Re} < 0.1$$

$$C_D = \frac{24}{\text{Re}} (1 + 0.14 \text{Re}^{0.7}) \text{ for } 0.1 \leq \text{Re} \leq 1000$$

$$\text{where } \text{Re} = \frac{v_t D_p \rho}{\mu}$$

where  $\mu$  is the fluid viscosity (Pa s).

Consider uniform spherical iron pellets with  $D_p=0.5$  mm and  $\rho_p = 7860$  kg/m<sup>3</sup> that are falling in air ( $\rho = 1.23$  kg/m<sup>3</sup>  $\mu=1.79 \times 10^{-5}$  Pa s). Determine the terminal velocity using the method of your choice.