

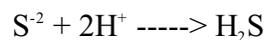
Chemical Characteristics of Water: Gases

Gases found in water include nitrogen (N₂), oxygen (O₂), carbon dioxide (CO₂), hydrogen sulfide (H₂S), ammonia (NH₃) and methane (CH₄).

- first three are common gases
- remaining are the result of bacterial metabolism and respiration; hydrogen sulfide from bacterial reduction of sulfate under anaerobic conditions, while ammonia and methane are derived from anaerobic decomposition of organic matter

▶ *hydrogen sulfide*

organic matter + sulfate (SO₄⁻²) bacteria sulfide (S⁻²) + H₂O + CO₂



- colourless, inflammable and rotten egg odour
 - low odour threshold that is quickly lost (Droste, 1997:363)
 - (a) normal: 0 ppm
 - (b) eye irritation: 10 ppm
 - (c) coughing (loss of smell in 2 to 16 min): 100 ppm
 - (d) red eyes: 200-300 ppm
 - (e) unconscious (death in 30 to 60 min): 300-700 ppm
 - (f) rapid unconscious (death in few min): 1000-2000 ppm
 - (g) LEL: 4300 ppm
- danger for sewers as it is very corrosive and especially in low slope sewers
 - H₂S can corrode reinforced concrete pipes (no concrete left above water line) by reacting with the calcium carbonate in the concrete
 - ASCE, 1985 indicated that during past four years, \$3.2 billion spent on sewer rehab to repair H₂S damage

▶ *methane*

- usually not found in untreated wastewater because oxygen present
- toxic to organisms
- high heat value
- explosion hazard

Solubility of Gases

Relationship exists between the solubility of the gas in water and the partial pressure of the gas in the atmosphere above the water → HENRY'S LAW

$$C_s = H_c P_g$$

where

- C_s = mole fraction or concentration of gas at equilibrium (saturation) in liquid phase; (mol/L) or (mg/L)
- H_c = Henry's Law Constant; (mol/L·atm⁻¹) or (mg/L·atm⁻¹)
- P_g = Partial pressure of gas in atmosphere, atm

Henry's Law constant can also exist in dimensionless form. Some dimensional values are given in the text.

- function of
 - ▶ solubility of gases
 - ▶ temperature of the water
 - ▶ purity of water, i.e. presence of suspended solids and salt
 - α -factor, for example = H_{ww}/H_{clean}

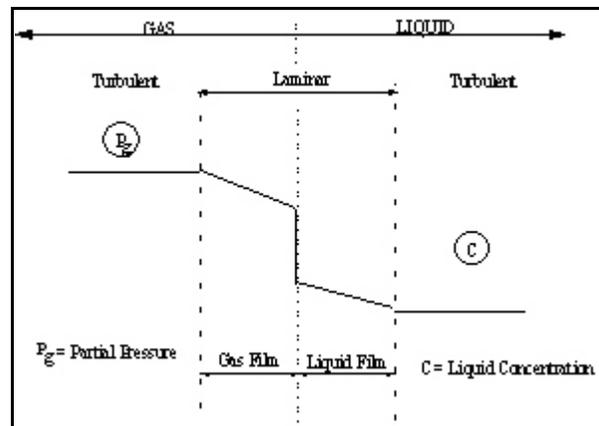
Gas Transfer

other according is described by two-film theory developed by Lewis and Whitman (1924). For addition of gas to liquid it is expressed as:

where

$$\frac{dm}{dt} = KA(C_s - C)$$

- dm/dt = mass transfer (g/h)
- K = coefficient of mass transfer (m/h)
- A = area of diffusion (m²)
- C_s = saturation conc. of liquid (g/m³)
- C = actual conc. of liquid (g/m³)



Now,

$$\frac{dm}{dt} = V \frac{dC}{dt} = KA(C_s - C) \quad \text{or} \quad \frac{dC}{dt} = K \frac{A}{V} (C_s - C)$$

Furthermore

where

$$\frac{1}{K} = \frac{1}{k_l} + \frac{1}{k_g H_c}$$

k_l = liquid phase mass transfer coefficient (m/h)
 k_g = gas phase mass transfer coefficient (m/h)

However, for many volatile compounds (dimensionless $H_c > 0.1$), $k_l \ll k_g$, making mass transfer liquid phase controlled. Accordingly, K is replaced with K_L .

Furthermore, A/V is A/V normally not measurable, and it is replaced with a , specific area. Therefore,

$$K \left(\frac{A}{V} \right) = K_L a \quad \Rightarrow \quad \frac{m}{h} \left(\frac{m^2}{m^3} \right) = \frac{1}{h}$$

where, $K_L a$ = overall mass transfer coefficient (1/h). Giving,

$$\frac{dC}{dt} = K_L a (C_s - C)$$

Integration and rearranging gives:

$$\frac{C_s - C_t}{C_s - C_o} = e^{-(K_L a)t}$$

where C_t = liquid concentration at any time t (g/m^3) or (mg/L)
 C_o = initial liquid concentration (g/m^3) or (mg/L)

For the situation of gas leaving the solution (VOLATILIZATION), then use:

$$\frac{C_t - C_s}{C_o - C_s} = e^{-(K_L a)t}$$

For temperature change of $K_L a$, use $\theta = 1.024$ for all temps.