Units and Dimensions

Introduction

If you're here, you may be new to Chemical Engineering (ChemE). ChemE is a branch of engineering that applies physical sciences (physics and chemistry), life sciences (biology, microbiology), together with mathematics and economics to processes that convert raw materials or chemicals into more useful or valuable forms.

A defining feature of a good chemical engineer is knowledge of units and dimensions, which are essential for communicating, analyzing, and solving engineering problems. This lesson introduces the mathematical foundations and practical applications of units and dimensions in ChemE.

Key Concepts

- Definitions
- Unit Systems
- Dimensional Analysis
- Unit Conversions
- Recap

Definitions

Units are standardized quantities used to specify measurements (e.g., meter, kilogram, second). **Dimensions** refer to the physical nature of a quantity (e.g., length, mass, time).

For example, velocity has the dimension of length/time ([L/T]) and can be measured in units such as m/s or ft/s. In equations, dimensions are often represented by symbols: [L] for length, [M] for mass, [T] for time. Temperature may be [K] or θ.

Example: The area of a rectangle is given by

$$A = l \times w$$

where both l and w have the dimension [L]. Thus,

$$[A] = [L] \times [L] = [L^2]$$

Unit Systems

Chemical engineers commonly use two unit systems: **SI (International System of Units)** and **Imperial (Customary)**. SI units are based on meters, kilograms, and seconds, while Imperial units use feet, pounds, and seconds. Being able to work in both systems and convert between them is a key skill.

- SI: meter (m), kilogram (kg), second (s), mole (mol), kelvin (K)
- Imperial: foot (ft), pound (lb), second (s), gallon (gal), Fahrenheit (°F)

Example: Pressure in SI is measured in pascals (Pa):

$$1Pa = 1N/m = 1kg/(ms)$$

In Imperial, pressure is often measured in pounds per square inch (psi).

Dimensional Analysis

Dimensional analysis checks the consistency of equations and converts between units. Expressing all quantities in terms of fundamental dimensions verifies equivalence and avoids calculation errors. It is also useful for deriving relationships and scaling up processes.

Example: Force equation:

$$F = m \times a$$

Mass has dimension [M], acceleration [L/T$^{\mathbf{2}}$], so

$$[F] = [M][L][T^{-2}]$$

In SI, the unit is newton (N), where $1N = 1kgm/s$.

Dimensional Homogeneity: Every term in a physically meaningful equation must have the same dimensions. For example, in

$$s = ut + \frac{1}{2}at^2$$

all terms have dimension of length [L].

Unit Conversions

Unit conversions are essential in chemical engineering to switch between SI and Imperial or within a system. Always use conversion factors and dimensional analysis.

Example: Convert 10 feet to meters:

$$10ft \times \frac{0.3048m}{1ft} = 3.048m$$

Multi-step Conversion: Convert 50 psi to kPa:

$$50psi \times \frac{6894.76Pa}{1psi} \times \frac{1kPa}{1000Pa} = 344.74kPa$$

Recap

This lesson covered the importance of units and dimensions in chemical engineering, major unit systems, and how to use dimensional analysis and unit conversions. Mastery of these concepts is foundational for all future engineering coursework and professional practice. Always check equations for dimensional consistency and practice conversions to build confidence in calculations.