GDM201 Mass and Energy Balances

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Office hours: Tuesday, 14:00–16:00

Contents

- Dimensions and their units
- Some basic physical properties (concentration, density, temperature, heat and pressure)
- Principles and examples of mass balances
- Principles and examples of energy balances

Suggested readings

1) Toledo RT. 1994. ***Fundamentals of Food Process Engineering***. 2nd ed., Chapman & Hall, New York, NY.

Chapter 2: Units and dimensions, p.51-65.

Chapter 3: Material balances, p.66-108.

Chapter 5: Energy balances, p.132-159.

2) Özkan M, Cemeroğlu B, Türkyılmaz M. 2011. ***Gıda Mühendisliğinde Kütle ve Enerji Denklikleri***. 251 s, Gıda Teknolojisi Derneği Yayınları No: 43, Bizim Grup Basımevi, Ankara.

Class programme (14 weeks)

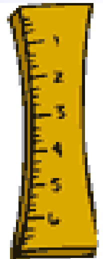
- **1st week:** Definition of dimensions, system of measurements (metric, English and SI unit systems)
- **2nd week:** Conversion of units
- **3rd week:** Definition and units of concentration and density
- **4th week:** Definition and units of temperature, heat and pressure

- **5th week:** Principles of mass balance, process flow diagrams, total mass balance and component mass balance
- **6th week:** Mass balance problems involved in sugar syrup preparation
- **7th week:** Mass balance problems involved in fruit juice, nectars, and jams and marmalade preparation

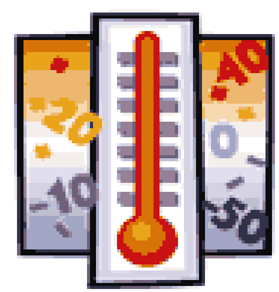
- **8th week:** Mass balance problems involved in dilution, dehydrtaion and concentration
- **9th week:** Midterm
- **10th week:** Mass balance problems involved in the multistage processes (filtration, crystallization and extraction)

- **11th week:** Principles of energy balance, heat (sensible and latent heat), enthalpy, specific heat of solids and liquids
- **12th week:** Enthalpy change during phase changes, specific heat of gases

- **13th week:** Properties of saturated and superheated steam, the use of steam tables, double interpolation from steam tables
- **14th week:** Energy balance problems involved in various food processes



DIMENSIONS, MEASUREMENT SYSTEMS AND UNITS



What is dimension and unit?

- **Dimension :** A physical quantity, which can be measured

  Example : Lenght, area, volume, mass, time, temperature

- **Unit :** The quantitative magnitude of a dimension

  Example : **length → m, cm, mm**

  mass → kg, g, mg

  time → second (s), hour (h)

Dimesions

Combination of base units

Base dimension

- Time
- Length
- Mass
- Temperature

Derived dimension

- Volume
- Velocity
- Density33

These dimensions are expressed in various units;

Various measurement systems are formed!!

Most common measurement systems

- **E**nglish **e**ngineering **s**ystem (ees)
- **C**entimeter-**g**ram-**s**econd system (cgs)
- **M**eter-**k**ilogram-**s**econd sytem (mks)

- **Ees** is primarily used by American and British chemical and food industries.
- Outside USA and Britain, industry uses **mks** system, and science uses **cgs** and **SI** unit systems.

Tabel 1.1 Systems of measurement (base units)

System	Length	Mass	Time	Temp.	Force	Energy
Ees	Foot	lb_m	s	°F	lb_f	BTU
Metric						
Cgs	cm	g	s	°C	Dyne	cal
mks	m	kg	s	°C	kg_f	kcal
SI	**m**	**kg**	**s**	**K**	**Newton**	**Joule**

SI Unit system

Units in various measurement system

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needs to be converted!!

To form a standart measurement system;

"**International System of Units" (SI)** was formed under "General Conference on Weights and Measures" in1960.

Tabel 1.2 Base dimensions and their units in **SI** system

Dimension	**Unit**	**Sembol**
Length	**meter**	**m**
Mass	**kilogram**	**kg**
Time	**second**	**s**
Electric current	amper	A
Temperature	**kelvin**	**K**
Amount of substance	**mole**	**mol**
Luminous intensity	candela	cd

Tablo 1.3 Derived dimensions and their units in SI system

Derived deimensions	Definition	Unit (symbol)
Area	length x length	m^2
Volume	length x length x length	m^3
Velocity	length/time	m/s
Acceleration due to gravity	length/(time x time)	m/s^2
density	mass/volume	kg/m^3
Concentration	mole/volume	mol/m^3
Specific volume	volume/mass	m^3/kg

Table 1.4 Some derived dimensions with assigned names, and their units and symbols

Dimesinsion	Unit	Symbol	Expression in terms of other units	Expression in terms of SI base units
Force	Newton	N		
pressure	Pascal	Pa		
Energy, work, heat	Joule	J		
Power	Watt	W		

Table 1.4 Some derived dimensions with assigned names, and their units and symbols

Dimesinsion	Unit	Symbol	Expression in terms of other units	Expression in terms of SI base units
Force	Newton	N		$kg\ m\ s^{-2}$
pressure	Pascal	Pa	$N\ m^{-2}$	$kg\ m^{-1}\ s^{-2}$
Energy, work, heat	Joule	J	$N\ m$	$kg\ m^{2}\ s^{-2}$
Power	Watt	W	$J\ s^{-1}$	$kg\ m^{2}\ s^{-3}$

Newton (N): The force that gives to a mass of 1 kg an acceleration of 1 m/s^2.

(Force=mass x accelaration due to gravity)

(1 kg'lık kütleye 1 m/s^2 ivme kazandıran kuvvete 1 Newton denir.)

Joule (J): The work done when a force of 1 N is displaced by a distance of 1 m in the direction of force. (1 N'luk kuvvetin kendi doğrultusunda 1 m yol almasıyla yapılan işe, 1 Joule denir.) Heat, energy and work are all in the same dimension.

(Energy=force x length)

- **Pressure** (Pa): Force per unit area applied in a direction perpendicular to the surface of an object. (Birim alana etki eden kuvvete basınç denir.) (Pressure=force/area)

- **Watt** (W): The power that gives rise to the production of energy at the rate of 1 J/s. (Birim zamanda yapılan işe ya da enerjiye, güç denir.)

  (Power=Energy/time)

Tablo 1.5 Examples of SI-derived units expressed by means of special names

Diemsion	Formula	Symbol	Expression in terms of SI base units
Viscosity	Pressure x time		
Heat capacity	Energy / Temp.		
Specific heat capacity	Energy / (mass x Temp)		
Thermal conductivity	Power / (length x Temp)		

Tablo 1.5 Examples of SI-derived units expressed by means of special names

Diemsion	Unit	Symbol	Expression in terms of SI base units
Viscosity	Pascal second		
Heat capacity	Joule / Kelvin		
Specific heat capacity	Joule / (kilogram x Kelvin)		
Thermal conductivity	Watt / (meter x Kelvin)		

Tablo 1.5 Examples of SI-derived units expressed by means of special names

Diemsion	Unit	Symbol	Expression in terms of SI base units
Viscosity	Pa s	Pa s	kg m^{-1} s^{-1}
Heat capacity	J / K	J K^{-1}	kg m^2 s^{-2} K^{-1}
Specific heat capacity	J / (kg x K)	J kg^{-1} K^{-1}	m^2 s^{-2} K^{-1}
Thermal conductivity	W / (m x K)	W m^{-1} K^{-1}	m kg s^{-3} K^{-1}

Tablo 1.6 Prefixes recommended for use in SI

Prefix	Multiple	Symbol
tera	10^{12}	T
giga	10^{9}	G
mega	10^{6}	M
kilo	**1000**	**k**
hekto	10^{2}	h
deka	10^{1}	da
deci	10^{-1}	d
centi	10^{-2}	c
mili	10^{-3}	m
micro	10^{-6}	μ
nano	10^{-9}	η
pico	10^{-12}	p
femto	10^{-15}	f

Capital letter

Lower case letter

- 1 g = 10^3 mg = 10^6 µg = 10^9 ng = 10^{12} pg
- 1 m = 10^3 mm = 10^6 µm = 10^9 nm = 10^{12}pm

- A dimension should be expressed as a numerical quantity and a unit must be such that the numerical quantity is between **0.1 ile 1000**.

- Examples:

  10,000 cm ….. M.

  0,0000001 m …. µm.

  10,000 Pa ….. kPa