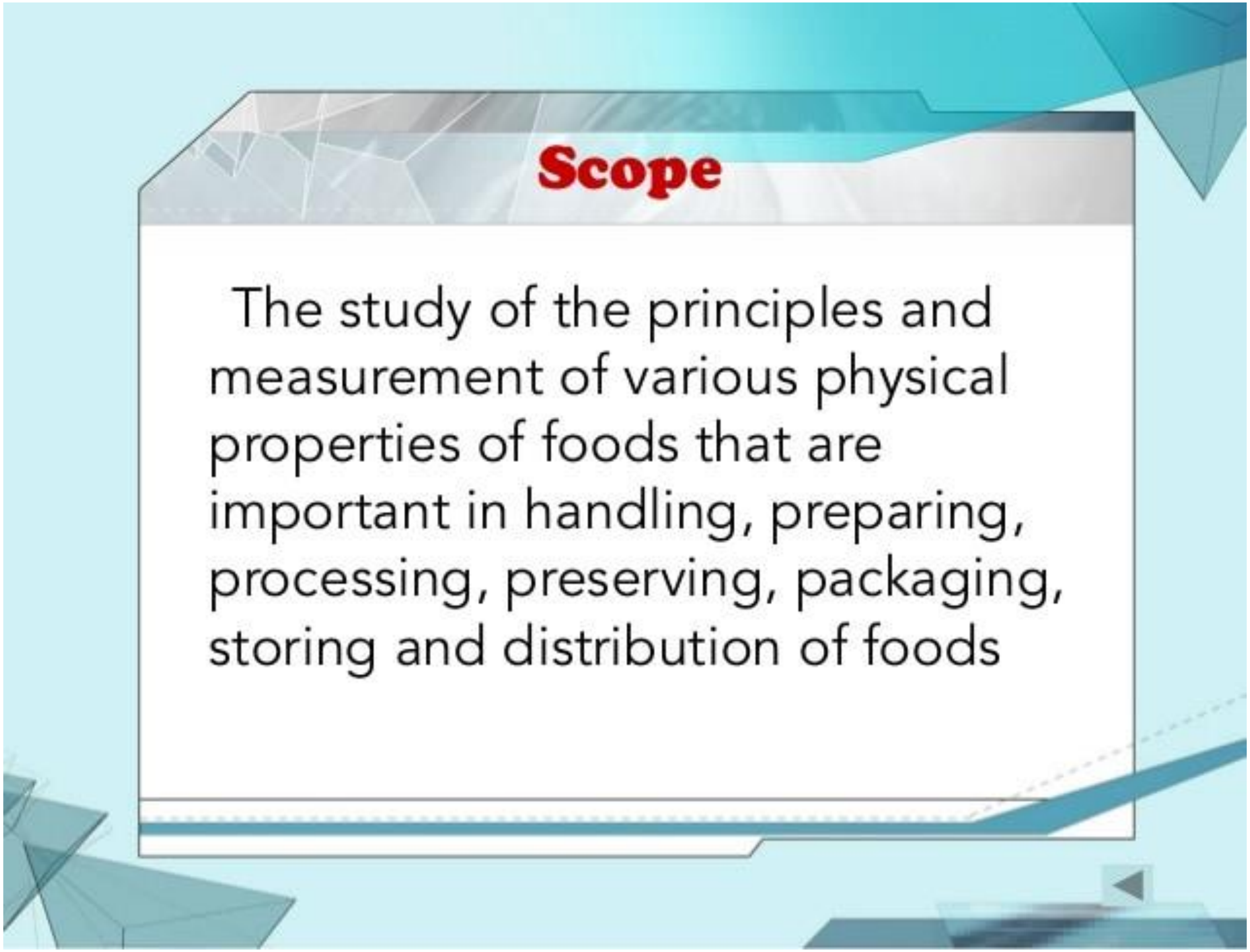
FDE449 Physical Properties of Foods

Instructor:

Professor Ayla Soyer


Scope
The study of the principles and measurement of various physical properties of foods that are important in handling, preparing, processing, preserving, packaging, storing and distribution of foods

Course objectives

Physical properties important for foods

- Define and describe physical properties of foods that measure the overall quality of fresh and prepared foods.
- Provides quantitative knowledge of many of the physical properties such as density, thermal conductivity, viscosity, etc.
- Makes understanding the physical properties of foods is important as they are used in **process design, product and process optimization**, product development, food quality control and food process modeling.

Learning outcomes

- Discuss the role of physical properties, in conjuction with chemical, biochemical and microbiological aspects, in determining food safety and quality
- Use the physical parameters to design appropriate conditions for food processing.
- Explane rheological properties of foods.
- Gıdaların ısıl özelliklerini ve ölçüm yöntemlerini açıklar.
- Define surface properties and measurement methods of foods.
- Explane electromagnetic properties of foods.

Contents

The foundations on which the physical properties of foods are based

Size, shape, volume, density and specific gravity

Surface properties of foods; surface activity, emulsion properties and emulsified foods, Foam formation, gel formation and foods produced by these processes

Thermal properties of foods; Calculation of thermal conductivity properties and thermal conductivity coefficient in different foods

Rheological properties of foods; texture, viscosity, consistency definitions

Dielectric properties of foods

References

Şahin, S., Şumnu, S.G. 2006. Physical Properties of Foods. Springer Science, 257 p., Business Media, LLC., United States of America.

Rao, M.A., Rizvi, S.S.H., Datta, A.K. 2005. Engineering Properties of Foods. 3rd Ed., CRC Press, Taylor & Francis Group, FL, USA.

Lewis, M.J. 1996. *Physical Properties of Foods and Food Processing Systems*. Wood Head Publishing Ltd., pp. 1-358.

Fennema, O.R. 1996. *Food Chemistry*. (Chapter 3–Dispersed systems). 3rd ed., Marcell Dekker, Inc., pp. 96-151.

COURSE ASSESSMENT AND EVALUATION		
method	number	Contribution margin (%)
Mid-term exam	1	30
Homework/ Quize	1	20
Final exam	1	60
Total	2	110

Physical properties of Foods

Content:
*Fundamental units,
*Size

Dimensions and units

- A physical property that can be measured or observed is qualitatively complemented by a dimension.
- For example, concepts such as length, area, volume, mass, time, force, temperature, and energy are each a dimension.
- The quantitative size of a dimension is specified in a unit. That is, each dimension must be given with a unit.
- For example, the unit of length is "metre"
- The unit of time can be specified as "second".

The size of an object or phenomenon does not change, but its unit may be different.

e.g:

If 400 W is transferred from a 100 m^2 surface, 4 W/m^2 from the same 1 m2 surface or from the same 1 m2 surface.

14 400 J/ m^2 h means heat transfer.

DIMENSIONS AND UNITS

Definition:

Dimensions are basic concepts of physical measurements such as:

- Length = [L]
- Time = [T]
- Mass = [M]
- Temperature = [θ]

Units are terms that precede and describe the dimensions.

Dimension

- Basic dimensions

  *mass

  *distance/lenth

  *time
- Composite dimensions:

  *distance/time (speed)

  *distance x distance (area)

  *mass/volume (density) etc.

Units used in the expression of dimensions

- Foot-pound-second system (British (Imperial) Engineering System (ees),
- Centimeter-gram-second system (cgs) and
- meter-kilogram-second system (mks).

The meter-kilogram-second system is also; It is also referred to as "meter-kilogram-second-ampere system"

abbreviation:mksa or simply "metric system".

Fundamental units for three main systems of measurement

Property	SI system	Cgs system	British (Imperial) system
Mass	kilogram (kg)	gram (g)	pound (lb)
Lenght	metre (m)	centimetre (cm)	foot (ft)
Time	second (s)	second (s)	second (s) sour (s)
Temperature	kelvin (K) or degree Celsius (^{o}C)	kelvin (K) degree Celsius (^{o}C)	Degree Fahrenheit (^{o}F)

Basic dimensions and units of the SI system

Dimension	Unit	Symbol
Lenght	meter	L
Mass	Kilogram	M
Time	Second	T
Electric current	Ampere	I
Temperature	Kelvin	K
Amount of substance	Mole	N
Luminous intensity	candela	J

Dimensions and units derived in the fps, mks and cgs system

Derived	Fps units	mks units	cgs units
Area	ft^2	m^2	cm^2
Volume	ft^3	m^3	cm^3
Density	lb_m/ft^3	kg/m^3	g/cm^3
Acceleration	Ft/s^2	m/s^2	cm/s^2
Force	lb_f	$kg\ m/s^2 = j/m = N$	$g\ cm/s^2$ or dyne
Energy	$Ft\text{-}lb_f$	$kg\ m^2/s^2 = N\ m = J$	$g\ cm^2/s^2$ = erg
Pressure	Psia, psig, atm	$kg/s^2\ m = N/m^2$ = Pa, atm	$g/s^2\ cm$ = $dyne/cm^2$, atm

- **Force:** The unit of force in the SI system is Newton (N). The force that accelerates 1 kg mass by 1 m/s^2 is called 1 Newton (N). According to this:

  $$1\ (N) = 1\ (kg) \times 1\ (m/\ s^2)$$

- **Energy:** Force x length. Since the unit of force (N) is the unit of length (m) in the SI system, the unit of energy is:

$$\text{Enerji} = N \times m = (kg\ m/\ s^2) \times m = kg\ m^2/\ s^2$$

This unit of energy is called joule (J). Therefore, the work done by a force of 1 Newton traveling 1 meter in its own direction is called 1 joule (J). Heat, work, and energy are dimensions of the same kind.

- **Power:** The work done per unit time is called power. In the SI system, the unit of power is taken in units of work (N x m) and time in seconds (s):

- $$\text{Power} = \frac{N\ m}{s} = \frac{(kg\ \ m/\ \ s^2)\ m}{s} = \frac{kg\ \ m^2/\ s^2}{s} = \frac{J}{s}$$

- This unit of power is called Watt (W), So:

$$W = \frac{J}{s}$$

- As electrical power unit 1 W= 1 (A) x 1 (V)
- As heat and work unit 1 W = J/s
- **Pressure :** It is the force per unit area unit in the SI system:

$$\text{Pressure} = \frac{\text{Force (F)}}{\text{Area (A)}} = \frac{N}{m^2}$$

Pressure is measured in:

Newtons per square metre (N/m^2), which are also called **pascals (Pa).**

Pressure can also be measured in:

Newtons per square millimetre (N/mm^2)

Newtons per square centimetre)N/cm^2)

- Since the pascal pressure unit is very small, kPa or bar units are used.

$$1 \text{ bar} = 10^5 \text{ Pa } (\text{N/ } \text{m}^2) = 0.1 \text{ MPa}$$

1 bar is approximately equal to 1 atm.

Measuring pressure is also be made in terms of a height or head of fluid.

For example, a pressure of 1 atm will support a column of mercury 760 mm in height when a simple barometer is set up.

The pressure is generally represented in following terms.

- *Atmospheric pressure*
- *Gauge pressure*
- *Vacuum (or vacuum pressure)*
- *Absolute pressure*

Atmospheric Pressure (Patm):

- It is the pressure exerted by atmospheric air on any surface. It is measured by a barometer. Its standard values are;
- 1 P_{atm} = 760 mm of Hg i.e. column or height of mercury
- $= \rho.g.h. = 13.6 \times 10^3 \times 9.81 \times 760/1000$
- $= 101.325$ kN/m^2 = 101.325 kPa
- = 1.01325 bar

Gauge Pressure (P_{gauge}):

It is the pressure of a fluid contained in a closed vessel. It is always more than atmospheric pressure. It is measured by an instrument called pressure gauge (such as Bourdon's pressure gauge). The gauge measures pressure of the fluid (liquid and gas) flowing through a pipe or duct, boiler etc. irrespective of prevailing atmospheric pressure.

Vacuum (Or Vacuum pressure) (P_{vacc}):

- It is the pressure of a fluid, which is always less than atmospheric pressure. Pressure (i.e. vacuum) in a steam condenser is one such example.

Absolute Pressure (P_{abs}):

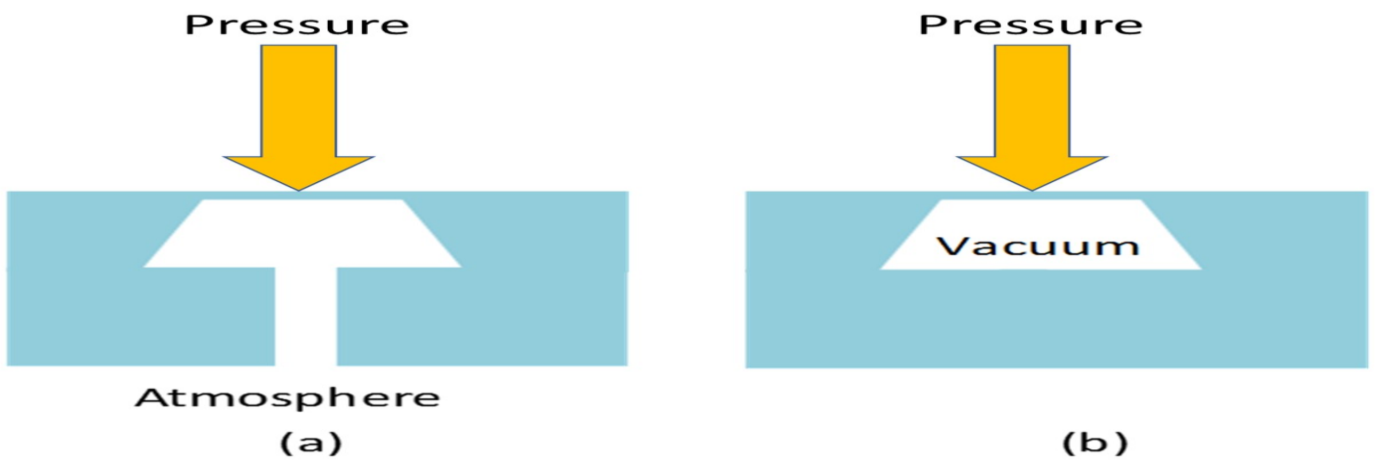
- It is that pressure of a fluid, which is measured with respect to absolute zero pressure as the reference.

- Absolute zero pressure can occur only if the molecular momentum is zero, and this condition arises when there is a perfect vacuum.

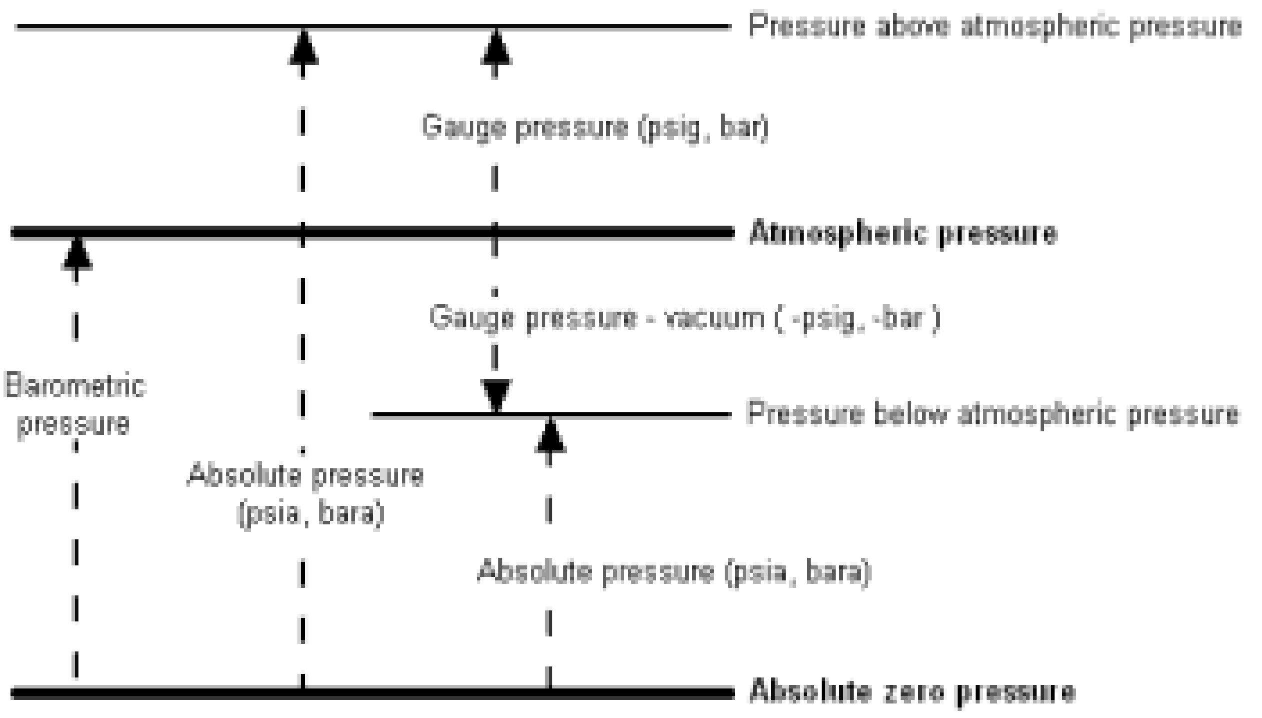
If a system has a pressure of less than 1 atm, it is said to be vacuum. According to this;

Vacuum = Atmospheric pressure – Absolute pressure

For example, if a pressure of 0.605 atm is measured in a hermetically sealed metal box, it means that there is a vacuum of 0.395 atm in the box (1- 0.605 =).



Relation Between Gauge ,Absolute and Atmospheric Pressure



Difference between Gauge ,absolute and atmospheric pressure

Vacuum measurement

- In the metric system, vacuum is measured as pascal (Pa), torr (Torr), millimeter mercury (mmHg) or micron (micrometer) mercury (μmHg) above the absolute zero pressure.

  1 Torr = 1 mm Hg = 10^3 μm Hg = 133.3 Pa

- If vacuum 4.6 Torr is measured, this means the pressure is 4.6 mm Hg above absolute zero pressure.

1 atm = 760 mm Hg

1 atm =101.3 KPa

Pressure used in food-processing operations

Operation	Pressure	Operation	Pressure
Homogenization	30-300 bar	Hot-air drying	Atmospheric pressure or slightly above
Reverse osmosis	40-80 bar	Spray drying	
Steam generation	6-10 bar	Evaporation	
Compressed air		Canning acid products	
Ultrafiltration		Blast freezing	
UHT processes	4-8 bar	Vacuum drying	1-100 kPa
Canning and bottling low-acid foods	1 bar	Vacuum evaporation	
		Vacuum filtration	
		Freeze drying	0.1 Torr to atmospheric pressure, normally below 4.6 Torr

Temperature

- Temperature is defined as the degree of hotness of a body.
- Expressed in terms of a specific scale.
- Scales are necessary for temperatures to be accurate and comparable

Two commonly used scales

- Fahrenheit (F)
- Celsius (C)

} Most commonly encountered

	Melting point of water	**Boiling point of water**
Celcius scale (^oC)	0	100
Fahrenheit scale (^oF)	32	212

Temperature conversion can be achieved by the following equations:

$^{o}C = (^{o}F - 32) \times 5/9$ or

$^{o}F = 9/5 \times {}^{o}C + 32$

Other scales used in temperature measurement:

- Kelvin (K)
- Rankine (^oR)

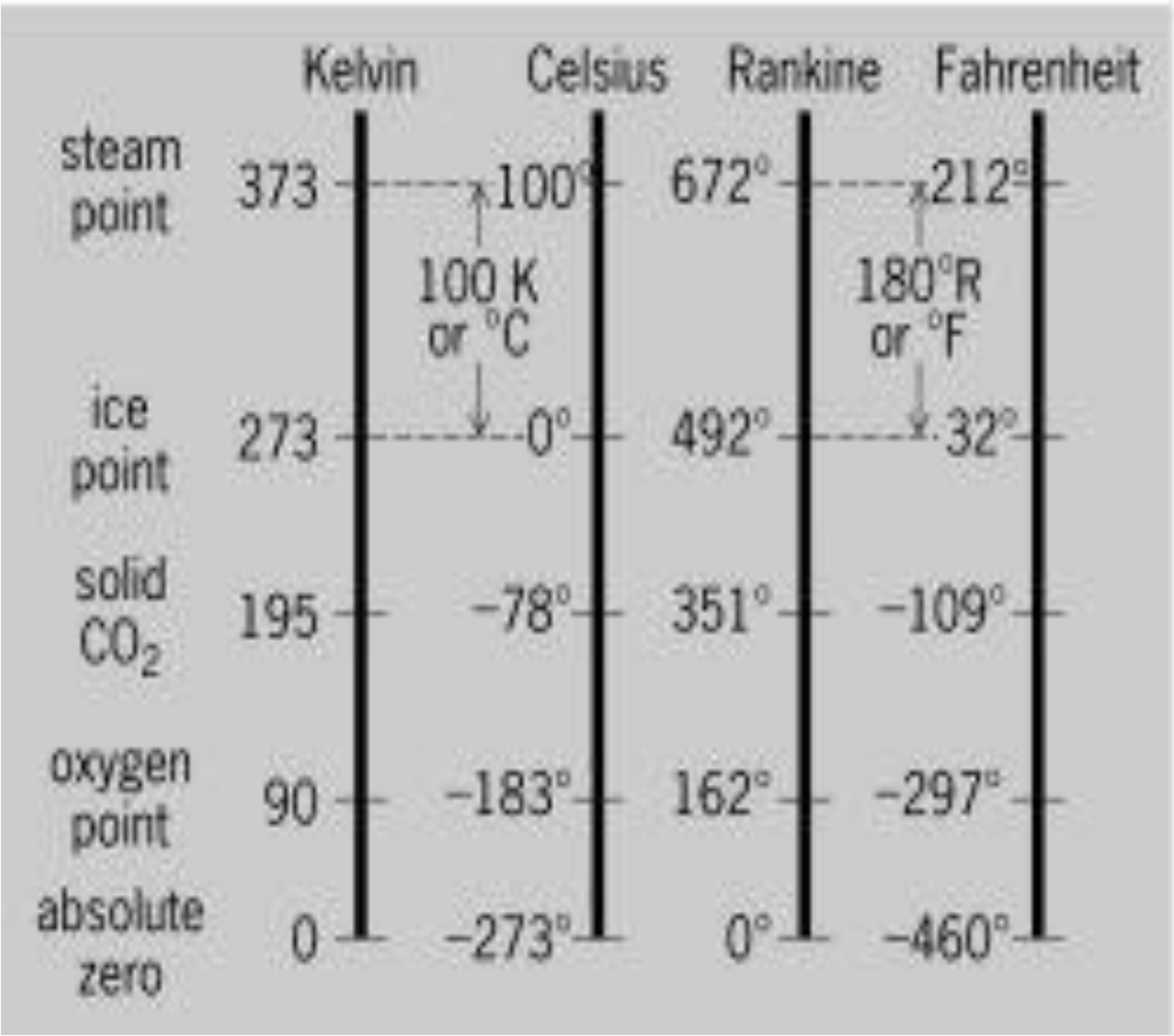
The Kelvin scale uses the same rating as the Celsius scale.

So 1 ^oC = 1 K

However, 0 K, taken as a fixed point on the Kelvin scale, corresponds to -273 ^oC on the Celcius scale.

A similar relationship is valid between the Rankine scale and the Fahrenheit scale. This time, 0 ^oR on the Rankine scale corresponds to -460 ^{o} F on the Fahrenheit scale. Likewise, 1 ^{o} R = 1 ^{o} F.

Scales used in temperature measurement



Example:

When water at 45 °C is heated to 90 °C:

- Specify the initial and final temperature of the water in K units.
- Specify the initial and final temperature of the water in °F.
- Calculate how many degrees the water has heated in Celsius (°C), Fahrenheit (°F), and Kelvin (K) units.

Example 2:

The temperature of a frozen (A) food was −20 °C, and the temperature of a (B) food was -20 °F.

- Calculate the temperature of (A) food in °F,
- Calculate the temperature of (B) food in °C.

Types of thermometer commonly used

Type of thermometer	Property
Mercury or alcohol thermometer	Expansion of a liquid
Constant-volume gas thermometer	Variation in pressure of a fixed volume of gas
Resistance thermometer and thermistor	Variation in electrical resistance
Thermocouple	Variation in electromotive force set up between two different metals

Food processing temperatures

Typical temperatures used for processing and storing foods

-40ºC to -20ºC	**Food freezing and storage of frozen foods**
-20ºC to -15ºC	Domestic deep-freeze cabinets.
-5ºC to -1ºC	Freezing points of most foods
-1ºC to +10ºC	Chilled storage and transportation
Ambient to 50ºC	Milling operations, freze drying, irradiation reverse osmosis, filtration, separation
50ºC to 100ºC	Vacuum evaporation, ultrafiltration, pasteurization, homogenization, hot-air drying, sterilization of acid products
110ºC to 125ºC	Sterilization of low-acid foods; reference temperature for thermal processing (121oC or 250oF)
140ºC to 150ºC	Roller drying, long life products (ultrahigh temperature (UHT))
150ºC to 250ºC	Spray drying, extrusion cooking, baking

Concentration

- Expressed in many ways, the most common:

  weight per unit weight (w/w) and

  weight per unit volume (w/v)

the concentration (w/w) is the mass of the substance divided by the total mass of the food.

e.g. a food containing 15% total solids (w/w) will contain 15 kg of solid matter in every 100 kg of food (solid or liquid).

Sugar concentrations ("Brix) are measured as kilograms of sugar per 100 kg of sugar solution.

- The concentration (w/v) is the mass of solute dissolved in unit volume of the solution and is expressed in kilograms per cubic metre (kg/ m^3) or grams per litre (g/l), where

$$1\ kg/m^3 = \frac{10^3\ g}{10^3\ l} = 1\ g/l$$

- The density of the solution will be required to convert from concentration (w/w) to concentration (w/v) and vice versa. The molar concentration or molarity (in units of M) is the concentration of solution in grams per litre divided by the molecular weight of the solute.

- The mole fraction of a component in a mixture is the number of moles of the substance compared with the total number of moles in the system and thus has no units.

Example:

- The density of a solution prepared by adding 20 kg of sucrose to 80 kg of water was determined as 1083 kg/m^3. If the total mass of the solution is 100 kg, what is the concentration of this solution?