THERMODYNAMIC PROPERTIES

A property of a system is a characteristic of the system which depends upon its state, but not upon how the state is reached. There are two general types of properties:

1. **INTENSIVE PROPERTY**:
   These properties do not depend on the mass (size or the amount of material) of the system it is a physical property of a system. of intensive properties include (Temperature and pressure).
2. **EXTENSIVE PROPERTY**:
   These properties depend on the mass of the system. Examples of extensive properties include (volume, internal energy, enthalpy and entropy). Extensive properties have two values (Total and Specific), total values have the usual units of that property while specific values have the same units divided by the units of mass. Extensive properties are often divided by mass associated with them to obtain the intensive properties.

$$Specific\ value\ of\ a\ property = Total\ value/Mass \qquad \ldots\ldots(1)$$

For example, if the volume of a system of mass m (kg) is V (m^3), then the specific volume of matter within the system is (υ (m^3/ kg) which is an intensive property. The following properties are some of the most important thermodynamic properties:

1. TEMPERATURE (T): is a thermal state of a body which distinguishes a hot body from a cold body. The temperature of a body is proportional to the stored molecular energy i.e., the average molecular kinetic energy of the molecules in a system. (A particular molecule does not have a temperature, it has energy. The gas as a system has temperature). Instruments for measuring ordinary temperatures are known as thermometers and those for measuring high temperatures are known as pyrometers.

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Several temperatures measuring scales came up from time to time. Different temperature scales have different names based on the names of persons who originated them and have different numerical values assigned to the reference states.

a. CELSIUS SCALE OR CENTIGRADE SCALE: Anders Celsius gave this Celsius or Centigrade scale using ice point of (0 °C) as the lower fixed point and steam point of (100 ºC) as upper fixed point for developing the scale. It is denoted by the letter (C). Ice point refers to the temperature at which freezing of water takes place at standard atmospheric pressure. Steam point refers to the temperature of water at which its vaporization takes place at standard atmospheric pressure. The interval between the two fixed points was equally divided into 100 equal parts and each part represented (1ºC).

b. FAHRENHEIT SCALE: Daniel Gabriel Fahrenheit gave another temperature scale known as Fahrenheit scale and has the lower fixed point as (32 ºF) and the upper fixed point as (212ºF). The interval between these two is equally divided into 180 parts. It is denoted by the letter F. Each part represents (1ºF). Fahrenheit Scale is related to Celsius scale as follows:

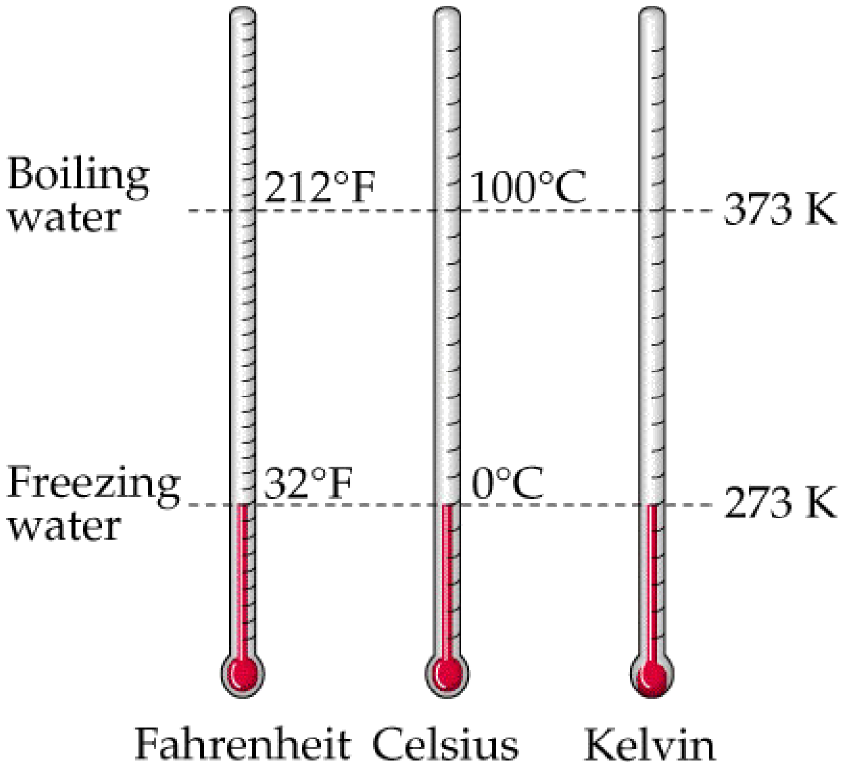
$$T_F = 1.8\, T_C + 32 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (2)$$

c. KELVIN SCALE: Kelvin scale proposed by Lord Kelvin is very commonly used in thermodynamic analysis. It also defines the absolute zero temperature. Zero-degree Kelvin or absolute zero temperature is taken as (-273 ºC). It is denoted by the letter K. It is related to Celsius scale as given below:

$$T_K = T_C + 273 \qquad \ldots\ldots\ldots\ldots(3)$$

d. RANKINE SCALE: it was developed by William John Macquorn Rankine, a Scottish engineer. It is denoted by the letter R. It is related to Fahrenheit scale as given below:

$$T_R = T_F + 460 \qquad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$



2- PRESSURE: it is the effect of a normal force acting on an area. If a force acts at an angle to an area, only the normal component enters the definition of pressure. The fundamental SI unit of pressure is (N/m^2), which is called a Pascal (Pa) or bar.

1bar = 10^5 N/m^2 = 10^5 Pa.

1 atm =101325 Pa= 1.01325 bar = 0.76 m (or 760 mm) Hg.

The pressure unit Pascal is too small for pressures encountered in practice. Therefore, its multiples kilo Pascal (1 kPa = 10^3 Pa) and mega Pascal (1 MPa = 10^6 Pa) are commonly used. Three other pressure units commonly used in practice which are: bar, standard atmosphere (atm) and pound-force per square inch (psi). The relationships between these units are:

1 atm = 101325 Pa = 14.696 psi

Most pressure measuring instrument measure the difference between the pressure of a fluid and the pressure of the atmosphere. This pressure difference is called a gauge pressure. In most thermodynamic relations absolute pressure must be used.

Absolute pressure is gage pressure plus the local atmospheric pressure:

$$P_{abs} = P_{gauge} + P_{atm} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

The word "gage" is generally used in statements of gage pressure.

e.g., (P = 200 kPa) gage. If "gage" is not present, the pressure will, in general, be an absolute pressure.

Atmospheric pressure is an absolute pressure and will be taken as (100 kPa) (at sea level), unless otherwise stated. A negative gage pressure is often called a vacuum pressure (P_{vac}) , and gages capable of reading negative pressures are vacuum gages , which indicates the magnitude of the difference between the atmospheric and absolute pressure so that:

$$P_{abs} = P_{atm} - P_{vac} \qquad \ldots\ldots\ldots\ldots\ldots..(6)$$

Figure (1) shows the relationships between absolute and gauge pressure,

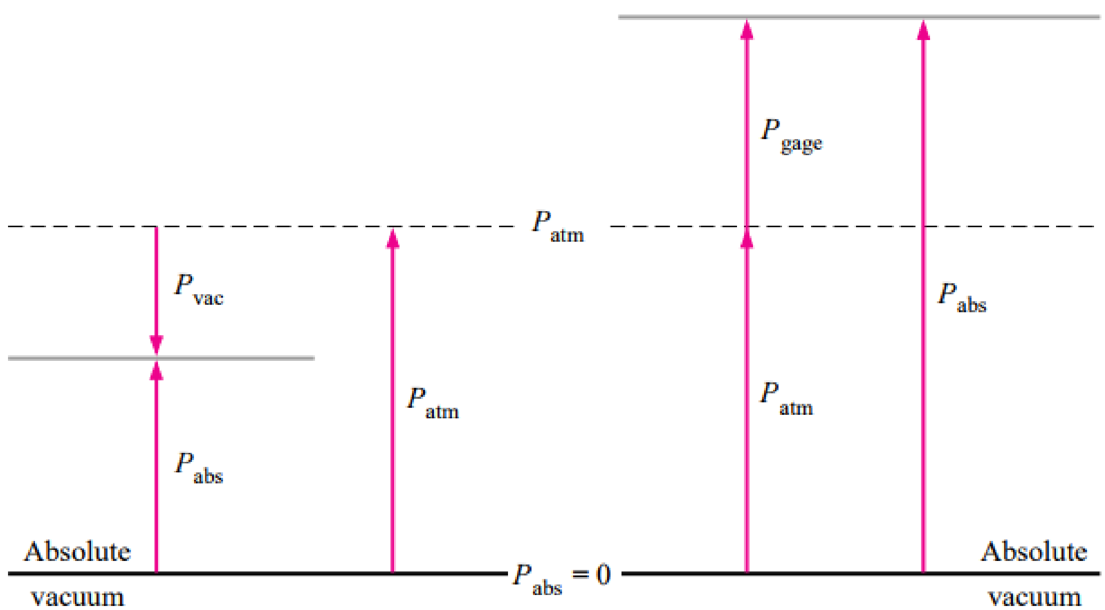


Figure (1) Absolute, gage, and vacuum pressures.

Example (1): A vacuum gage connected to a chamber reads (5.8 psi) at a location where the atmospheric pressure is (14.5 psi). Determine the absolute pressure in the chamber.

Solution: $P_{abs} = P_{atm} - P_{vac} = 14.5 - 5.8 = 8.7\ psi$

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3. VOLUME (V): is the quantity of three-dimensional space enclosed by a closed surface, for example: the space that a substance (solid, liquid, gas or plasma) occupies or contains. Volume is an independent property.

4. INTERNAL ENERGY (U): is a property consisting of the combined molecular kinetic and potential energies. This property is derived from the first law of thermodynamics. Internal energy is a dependent property.

5. ENTHALPY (H): is a thermodynamic quantity equivalent to the total heat content of a system. It is equal to the internal energy of the system plus the product of pressure and volume. Enthalpy is a dependent property.

6. ENTROPY (S): is a thermodynamic quantity representing the unavailability of a system's thermal energy for conversion into mechanical work, often interpreted as the degree of disorder or randomness in the system. This property is derived from the second law of thermodynamics. Entropy is a dependent property.

4. ZEROTH LAW OF THERMODYNAMICS

Zeroth law of thermodynamics' states that if two systems are each equal in temperature to a third, they are equal in temperature to each other.

For example, we have three systems, System '1' may consist of a mass of gas enclosed in a rigid vessel fitted with a pressure gauge. If there is no change of pressure when this system is brought into contact with system '2' a block of iron, then the two systems are equal in temperature (assuming that the systems 1 and 2 do not react each other chemically or electrically). Experiment reveals that if system '1' is brought into contact with a third system '3' again with no change of properties then systems '2' and '3' will show no change in their properties when brought into contact provided, they do not react with each other chemically or electrically. Therefore, '2' and '3' must be in equilibrium. This law was enunciated by R.H. Fowler in the year 1931. However, since the first and second laws already existed at that time, it was designated as zeroth law so that it precedes the first and second laws to form a logical sequence.

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