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Dept. of Chem. & Petrochemical Engineering
Subject : Physics
First Stage

Physics

Chapter 7– Temperature and Thermodynamics

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Volume Expansion

The change in volume is proportional to the original volume and to the change in temperature.

$\Delta V = \beta V_i \Delta T$

- β is the coefficient of volume expansion.
- For a solid, $\beta = 3\alpha$
- For a liquid or gas, β is given in the table

Area Expansion

The change in area is proportional to the original area and to the change in temperature:

- $\Delta A = 2\alpha A_i \Delta T$

An Ideal Gas

For gases, the interatomic forces within the gas are very weak.

State variables describe the state of a system.

Variables may include:

- Pressure, temperature, volume, internal energy

The state of an isolated system can be specified only if the system is in thermal equilibrium internally.

- For a gas in a container, this means every part of the gas must be at the same pressure and temperature.

It is useful to know how the volume, pressure, and temperature of the gas of mass m are related.

The equation that interrelates these quantities is called the **equation of state.**

The **ideal gas model** can be used to make predictions about the behavior of gases.

The Mole

The amount of gas in a given volume is conveniently expressed in terms of the number of moles, n.

One **mole** of any substance is that amount of the substance that contains **Avogadro's number** of constituent particles.

- Avogadro's number is $N_A = 6.022 \times 10^{23}$
- The constituent particles can be atoms or molecules.

The number of moles can be determined from the mass of the substance:

$$n = \frac{m}{M}$$

- M is the molar mass of the substance.
  - Can be obtained from the periodic table
  - Is the atomic mass expressed in grams/mole
    - Example: He has mass of 4.00 u so M = 4.00 g/mol
- m is the mass of the sample.
- n is the number of moles.

Gas Laws

When a gas is kept at a constant temperature, its pressure is inversely proportional to its volume (Boyle's law).

When a gas is kept at a constant pressure, its volume is directly proportional to its temperature (Charles and Gay-Lussac's law).

When the volume of the gas is kept constant, the pressure is directly proportional to the temperature (Guy-Lussac's law).

Ideal Gas Law

The equation of state for an ideal gas combines and summarizes the other gas laws:

$$PV = nRT$$

This is known as the **ideal gas law.**

R is a constant, called the Universal Gas Constant.

- $R = 8.314$ J/mol · K = 0.08214 L · atm/mol · K

From this, you can determine that 1 mole of any gas at atmospheric pressure and at 0° C is 22.4 L.

It is common to call P, V, and T the **thermodynamic variables** of an ideal gas.

Example

Pure helium gas is admitted into a tank containing a movable piston. The initial volume, pressure and temperature of the gas are $15x10^{-3}m^3$, 200kPa and 300K respectively. If the volume is decreased to $12x10^{-3}m^3$ and the pressure is increased to 350KPa, find the final temperature of the gas.

- **Solution**

Since the gas can not escape from the tank then the number of moles is constant,

$$\frac{p_1V_1}{T_1}=\frac{p_2V_2}{T_2}$$

$$T_2=(\frac{p_2V_2}{p_1V_1})T_1=\frac{3.5\,atm\,.\,12\,liters}{2\,atm\,.\,15\,liters}(300K)=420\,K$$

Internal Energy

Internal energy is all the energy of a system that is associated with its microscopic components.

- These components are its atoms and molecules.
- The system is viewed from a reference frame at rest with respect to the center of mass of the system.

The kinetic energy due to its motion through space is not included.

Internal energy does include kinetic energies due to:

- Random translational motion
- Rotational motion
- Vibrational motion

Internal energy also includes potential energy between molecules

Heat

Heat is defined as the transfer of energy across the boundary of a system due to a temperature difference between the system and its surroundings.

The term heat will also be used to represent the amount of energy transferred by this method.

There are many common phrases that use the word "heat" incorrectly.

Heat, internal energy, and temperature are all different quantities.

- Be sure to use the correct definition of heat.
- **One calorie** is the amount of energy transfer necessary to raise the temperature of 1 g of water from 14.5°C to 15.5°C.
  - The "Calorie" used for food is actually 1 kilocalorie.
  - The standard in the text is to use Joules.

more precise, measurements determined the amount of mechanical energy needed to raise the temperature of water from 14.5°C to 15.5°C.

1 cal = 4.186 J

- This is known as the **mechanical equivalent of heat.**

Heat Capacity

The **heat capacity**, C, of a particular sample is defined as the amount of energy needed to raise the temperature of that sample by 1°C.

If energy Q produces a change of temperature of ΔT, then $Q = C\Delta T$.

Specific Heat

Specific heat, c, is the heat capacity per unit mass.

If energy Q transfers to a sample of a substance of mass m and the temperature changes by ΔT, then the specific heat is

$$c \equiv \frac{Q}{m\,\Delta T}$$

The specific heat is essentially a measure of how thermally insensitive a substance is to the addition of energy.

- The greater the substance's specific heat, the more energy that must be added to a given mass to cause a particular temperature change.

The equation is often written in terms of Q : $Q = m\,c\,\Delta T$

Water has the highest specific heat of common materials.

Some Specific Heat Values

TABLE 20.1 *Specific Heats of Some Substances at 25°C and Atmospheric Pressure*

Substance	Specific Heat (J/kg · °C)	Substance	Specific Heat (J/kg · °C)
Elemental solids		*Other solids*	
Aluminum	900	Brass	380
Beryllium	1 830	Glass	837
Cadmium	230	Ice (−5°C)	2 090
Copper	387	Marble	860
Germanium	322	Wood	1 700
Gold	129	*Liquids*	
Iron	448	Alcohol (ethyl)	2 400
Lead	128	Mercury	140
Silicon	703	Water (15°C)	4 186
Silver	234	*Gas*	
		Steam (100°C)	2 010

Note: To convert values to units of cal/g · °C, divide by 4 186.

Example

A quantity of hot water at 91° C and another cold one at 12° C. How much kilogram of each one is needed to make an 800 liter of water bath at temperature of 35° C.

Solution

Assume the mass of hot water m_H and cold one is m_C,

800 liter of water is equivalent to 800 kg, *So* $m_H + m_C = 800$,

From the conservation of energy $m_H C_w (T_H - T_f) = m_C C_w (T_f - T_C)$

$T_H = 92°C$, $T_C = 12°C$, $T_f = 35°C$,

$$56\, m_H = 23\, m_C,$$

- *so*

$$m_C = 2.43\, m_H$$

- So by substitution

$$3.43\, m_H = 800,$$

$$m_H = 233\ kg, \text{ and } m_C = 567\ kg$$