VIVEKANAND EDUCATION SOCIETY'S POLYTECHNIC

Since 1962

Study Material

Program Code: Common to all 1st semester

Semester: 1

Course Name: Basic Science (Physics)

Course Code: 22102

Topic Name: Heat and Optics

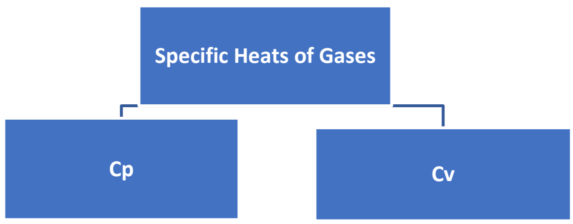
Topic Name: Heat and optics

UO3d: Determine the relation between specific heats for the given materials

LO4: Students will be able to determine the relation between specific heats for the given materials

Course Expert: Mrs. Deepa Gupte	**Date: 21/9/2020**

Concept Map:



Key words: Conduction, Convection , Radiation

Key Questions: What are different modes of heat transfer?

Key Definition/Formula: Conduction, Convection, Radiation, coefficient of thermal conductivity

Diagram /Picture:

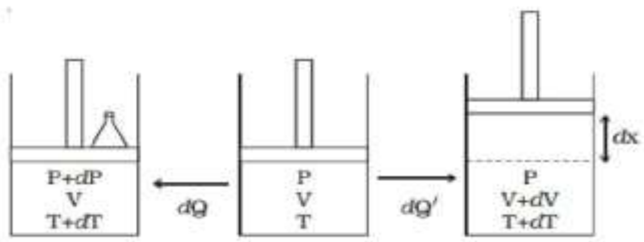


Fig. Meyer's relation

Notes:

Specific heat of substance (c): The specific heat of substance is defined as the quantity of heat required to raise the temperature of unit mass of substance through 1°C (or 1°K). Specific heat is denoted by symbol 'c'.

If Q is the quantity of heat supplied to a substance of having mass m and specific heat c and θ is the rise temperature of the substance, then the heat absorbed by the substance is given as
Heat absorbed = mass × specific heat × rise in temperature.

i.e, $Q = m \times c \times \theta \qquad \therefore \quad c = \dfrac{Q}{m \times \theta}$

Unit of specific heat (c): As we know, $c = \dfrac{Q}{m \times \theta}$

$$\therefore \quad c = \frac{Q}{m \times \theta} = \frac{J}{kg \times °K} \quad \text{or} \quad \frac{J}{kg \times °C}$$

Practically as well as theoretically it is noted that if a gas is heated at constant pressure its volume changes and if a gas is heated at constant volume its pressure changes, hence there are two specific heats of a gas. They are specific heat of a gas at constant volume (c_v) and specific heat of a gas at constant pressure (c_p)

Specific heat at constant volume (c_v): The quantity of heat required to increase the temperature of unit mass of gas by 1°K or 1°C, at constant volume is called specific heat of gas at constant volume (c_v).

Specific heat at constant pressure (c_p): The quantity of heat required to increase the temperature of unit mass of gas by 1°K or 1°C, at constant pressure is called specific heat of gas at constant pressure (c_p).

Molar specific heat at constant volume (C_v): The quantity of heat required to increase the temperature of one mole of gas by 1°K or 1°C, at constant volume is called specific heat of gas at constant volume (C_v).

Molar specific heat at constant pressure (C_p): The quantity of heat required to increase the temperature of one mole of gas by 1°K or 1°C, at constant pressure is called specific heat of gas at constant pressure (C_p).

Note: If 'M' is the molecular weight of the gas, then $C_v = M \times c_v$ and $C_p = M \times c_p$

Also 4200 J / kg0K = 4.2J / g0K = 1cal / g0K = 1Kcal / kg0K

Mayer's relation:
Consider one mole of a gas enclosed in a cylinder fitted with an air tight piston. Let P, V, and T be the initial values of pressure, volume and temperature of a gas.
Suppose that the piston is kept fixed and the gas is heated at constant volume so that its temperature increases by dT. The heat absorbed by the gas is given by
Heat absorbed = number of moles × molar specific heat × rise in temperature.
$= 1 \times C_v \times dT = C_v\, dT$
Similarly at constant pressure the temperature rises by dT. In this case, the gas expands and the heat absorbed by the gas is C_p dT
This heat absorbed at constant pressure is used in two different ways:
(i) Some part of heat is used to increase the temperature by dT, (i.e., C_v dT) and
(ii) The remaining part is used to perform work during expansion.(i.e., dW)

$$\therefore \quad C_p dT = C_v\, dT + dW \qquad \text{.................................... (1)}$$

Let A be the area of cross-section of piston and dx be its displacement of the piston during expansion. Then the work (dW) done is given by
Work = Force × displacement
= Pressure × area × displacement

$$\therefore \quad dW = P \times A \times dx$$

$\therefore \quad dW = P \times dV$ (as we know A × dx = dV, i.e., increase in the volume of gas)

$$\therefore \quad dW = PdV$$

Substituting $dW = PdV$ in equation (1), we get

$$\therefore \quad C_p dT = C_v\, dT + PdV \qquad \text{.................................... (2)}$$

For an ideal gas PV = RT, where R is universal constant.
As the pressure is constant and the volume and temperature have increased to $V + dV$ and $T + dT$, we write the gas equation as $P(V + dV) = R(T + dT)$

$$\therefore \quad PV + PdV = RT + RdT$$

$$\therefore \quad PdV = RdT$$ (as $PV = RT$)

Substituting $PdV = R\,dT$ in equation (2), we get

$$\therefore \quad C_p dT = C_v\, dT + R\, dT \qquad \text{.................................. (3)}$$

$$\therefore \quad C_p dT - C_v\, dT = R\, dT$$

$$\therefore \quad C_p - C_v = R \qquad \text{.................................. (4)}$$

All the quantities in this formula are expressed in the units of work (erg / joule). If however, the specific heats are expressed in the units of heat (cal / kcal) and R is expressed in units of work, the formula will be

$$\therefore \quad C_p - C_v = \frac{R}{J} \qquad \text{.................................. (5)}$$

(where J is mechanical equivalent of heat = 4200 J/kcal)

If M is the molecular weight of the gas, then equation (5) is written as

$$\therefore \quad C_p - C_v = \frac{R}{MJ} \qquad \text{................................ (6)}$$

This equation (4), (5) and (6) is known as Mayer's relation for the specific heat of a gas.

Ratio of specific heats: For a particular gas, C_v and C_p is always constant. Also C_p is greater than C_v.

$$\therefore \quad \frac{C_p}{C_v} = \text{cons tan t} = \gamma$$ (where γ is called adiabatic index)

$$\because \quad C_p \rangle C_v \qquad \therefore \quad \gamma \rangle 1$$

Value of γ = 1.66 for monoatomic gases

= 1.41 for diatomic gases

= 1.31 for triatomic gases

Link to YouTube/ OER/ video/e-book:

Key Take away: specific heat, Cp, Cv, Ratio of specific heat, adiabatic index

Formative Assessments

<22102>: < Common to all 1st semester>: <Common to all>: <Heat and Optics>: <UO3d: Determine the relation between specific heats for the given materials.>: <Assessments>: <Formative>

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Assessment Type: Formative Assessments:

Set 1: Question No 1	Set 1: Question No 2	Set 1: Question No 3
Specific heat capacity of a substance is equal to ________________________________.	Why specific heat at constant pressure is greater than specific heat at constant volume?	The quantity of heat required to increase the temperature of unit mass of gas by 1°K or 1°C, at constant volume is called ………………………
a) the amount of heat required to raise the temperature of a 1 kg of a substance by 1 °K.	a) Heat absorbed at constant pressure is used to increase temperature as well as to expand the gas.	a) specific heat of gas
b) the amount of heat required to raise the temperature of a substance by 1 °K.	b) Heat absorbed at constant volume is used to increase temperature as well as to expand the gas.	b) specific heat of gas at constant pressure.
c) the amount of heat required to change the phase of a substance from solid to liquid without any change in temperature.	c) Heat absorbed at constant pressure is used to decrease temperature as well as to expand the gas.	c) specific heat of gas at constant volume.
d) the amount of heat required to change the phase of a substance from liquid to gas without any change in temperature.	d) Heat absorbed at constant volume is used to decrease temperature as well as to expand the gas.	d) All of the above
Ans: <a>	Ans: <a>	Ans: <c>

Set 2: Question No 1	Set 2: Question No 2	Set 2: Question No 3
Mayer's relation is __________	Relation between C_P & C_V for gases is	If the ratio of few specific heats of a gas 1.4 and difference is 0.0808 then values of C_P & C_V
a) $C_P/C_V = r$	a) $C_P = C_V$	a) 0.2828 ; 0202
b) $C_P - C_V = 1$	b) $C_P > C_V$	b) 0.1414 ; 0.101
c) $C_P - C_V = R/J$	c) $C_P < C_V$	c) 0.4256 ; 0.304
d) $C_P - C_V = RJ$	d) $C_P = - C_V$	d) 1.4 ; 1
Ans: <c>	Ans: <b>	Ans: <a>

Practice Worksheet

<22102> : <Common to all 1st Semester> : < Common to all 1st Semester>: <Heat and optics>: <UO1c> : <Assessments> : <Worksheet>

< Mrs. Deepa Gupte >

Assessment Type: Practice Worksheets:

A) Heat capacity of a substance is defined as a. the amount of heat required to raise the temperature of a substance by 1 °K b. the amount of heat required to raise the temperature of a substance by 1 °C c. specific heat capacity × mass of the substance d. All of the above	B) Specific heat is - a. the specific temperature at which the substance is in solid state. b. the energy needed to increase the temperature of 1 gm of a substance by 1° C. c. the amount of heat conducted in 1 minute. d. the heat needed to increase the temperature of 1 gallon of water by 1° F.
Ans A: d	Ans B: b
C) The quantity of heat required to increase the temperature of unit mass of gas by 1°K or 1°C, at constant volume is called …………………….. a. specific heat of gas b. specific heat of gas at constant pressure. c. specific heat of gas at constant volume. d. All of the above	D) Assuming heat capacity of a 10 g of water to be 42 J/K, heat required to raise its temperature from 25 °C to 35 °C would be a. 42 J b. 420 J c. 4200 J d. None of the above
Ans C: c	Ans D: b