UNIT

3

Thermal Physics

POINTS TO REMEMBER

Thermal energy : It is a form of energy which is transferred between any two bodies due to the difference in their temperatures.

Temperature : It is the degree of hotness or coldness of a body

Absolute temperature : The temperature is measured in relation to absolute zero using the Kelvin scale.

Linear expansion : When a body is heated or cooled, the length of the body changes due to change in its temperature.

Areal expansion : There is an increase in the area of a solid object due to heating.

Superficial expansion : If there is an increase in the area of a solid object due to heating, then the expansion is called superficial expansion.

Cubical expansion : If there is an increase in the volume of a solid body due to heating, then the expansion is called as cubical expansion.

Real expansion : If a liquid is heated directly without using any container then the expansion is real expansion.

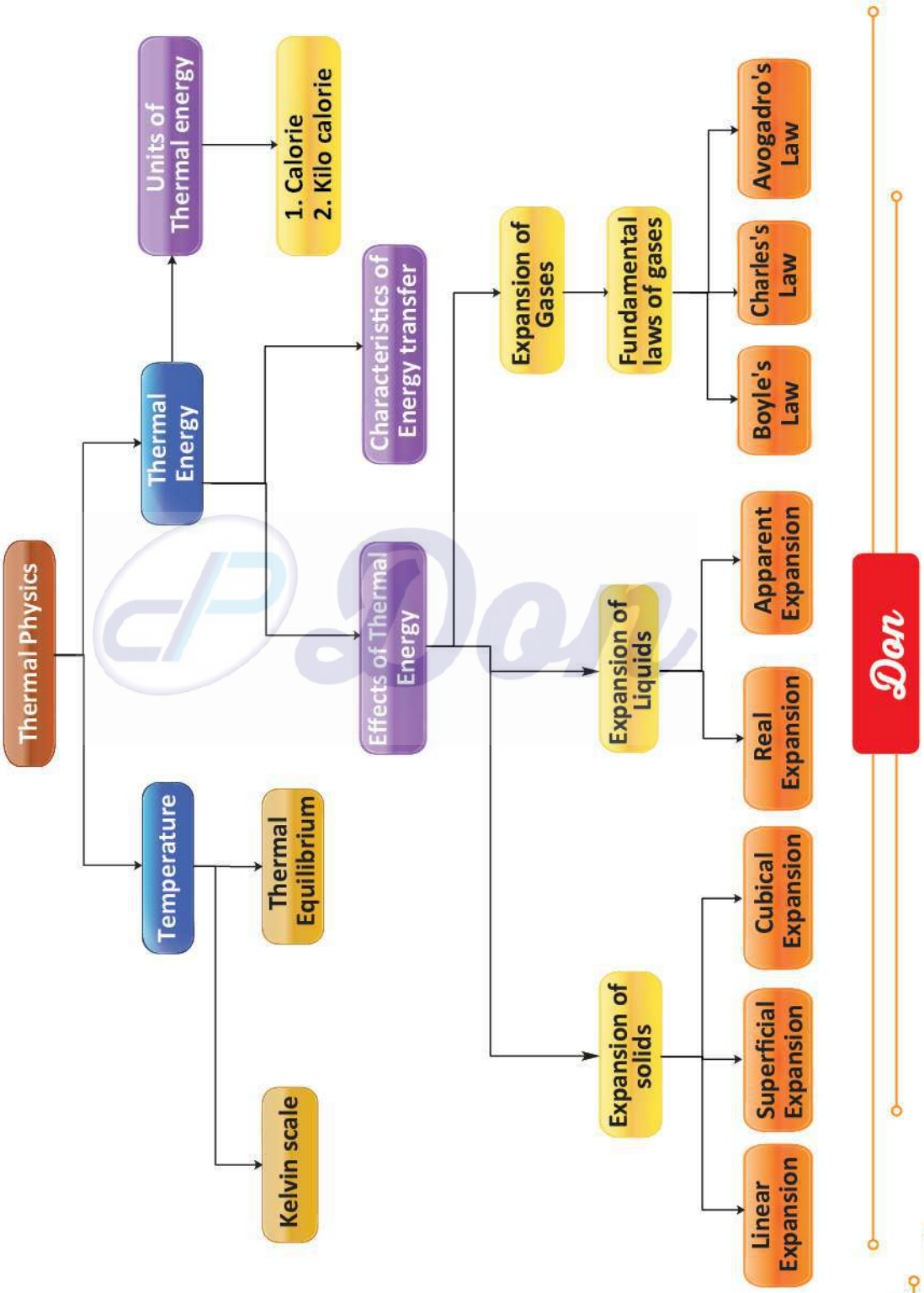
Apparent expansion : The expansion of a liquid is apparently observed without considering the expansion of the container.

Coefficient of linear expansion : It is the ratio of increase in the length of the body per degree rise in temperature to its unit length.

Coefficient of superficial expansion : It is the ratio of increase in the area of the body per degree rise in temperature to its unit volume.

Coefficient of real expansion : It is the ratio of true rise in the volume of the liquid per degree rise in temperature to its unit volume. The SI unit of coefficient of real expansion is K^{-1}.

MIND MAP



Boyle's law	: When the temperature of a gas is kept constant , the volume of a fixed mass of gas is inversely proportional to its pressure.P ∝1/V or PV = constant of a gas.
Charles's law	: When the pressure of a gas is kept constant , the volume of a gas is directly proportional to the temperature of the gas. V ∝ T or V/T = constant
Avogadro's law	: It states that at constant pressure and temperature , the volume of a gas is directly proportional to the number of atoms or molecules present in it. i.e. V ∝ n or V/n =constant.
Real gases	: If the molecules or atoms of a gases interact with each other with a definite amount of intermolecular or inter atomic force of attraction, then the gases are real gases.
Ideal gases	: Ideal gases obey Boyle's law, Charles's law and Avogadro's law.

Formulae

Relation between Celsius & Kelvin	$K = {}^{o}C + 273$
Relation between Fahrenheit and kelvin	$[K] = ({}^{o}F + 460) \times \frac{5}{9}$
Coefficient of cubical expansion	$\frac{\Delta V}{V_0} = \alpha_v \Delta T$
Coefficient of linear expansion	$\frac{\Delta L}{L_0} = \alpha_L \Delta T$
Coefficient of areal expansion	$\frac{\Delta A}{A_0} = \alpha_A \Delta T$ (or) $2 \times \alpha_L$
Coefficient of cubical expansion	$\alpha_v = 3 \times \alpha_L$
Boyle's law	$P \propto \frac{1}{V}$ (or) PV = constant
Charles's law	$V \propto T$ (or) $\frac{V}{T}$ = constant
Avogadro's law	$V \propto n$ (or) $\frac{V}{n}$ = constant
Ideal gas equation	PV = nRT ; n–No. of moles R – Universal gas constant (8.314J mol^{-1} K^{-1})

Textbook Evaluation

I. Choose the most suitable answer from the given four alternatives and write the option code and corresponding answer:

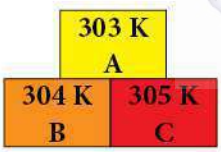
1. **The value of universal gas constant** ★★
   a) 3.81 $mol^{-1} K^{-1}$ b) 8.03 $mol^{-1} K^{-1}$
   c) 1.38 $mol^{-1} K^{-1}$ d) 8.31 J $mol^{-1} K^{-1}$

2. **If a substance is heated or cooled, the change in mass of that substance is**
   a) positive b) negative
   c) zero d) none of the above

3. **If a substance is heated or cooled, the linear expansion occurs along the axis of**
   a) X or –X b) Y or –Y
   c) both a and b d) a or b

4. **Temperature is the average _____ of the molecules of a substance**
   a) difference in K.E and P.E
   b) sum of P.E and K.E
   c) difference in T.E and P.E
   d) difference in K.E and T.E

5. **In the Given diagram, the possible direction of heat energy transformation is**



★★

   a) A ← B, A ← C, B ← C b) A→B, A→C, B→C
   c) A→B, A←C, B→C d) A←B, A→C, B←C

Ans:

1.	d)	8.31 J $mol^{-1} K^{-1}$	4.	c)	difference in T.E and P.E
2.	c)	Zero	5.	a)	A ← B, A ← C, B ← C
3.	d)	a or b			

II. Fill in the blanks

1. **The value of Avogadro number _____.** ★★
2. **The temperature and heat are _____ quantities.**
3. **One calorie is the amount of heat energy required to raise the temperature of _____ of water through_____.** ★
4. **According to Boyle's law, the shape of the graph between pressure and reciprocal of volume is _____.**

Ans:

1.	6.023×10^{23}	3.	1 gram, 1° C
2.	Scalar	4.	Straight line

III. State whether the following statements are true or false, if false explain why.

1. **For a given heat in liquid, the apparent expansion is more than that of real expansion.** ✶✶ **False**

   For a given heat in liquid, the real expansion is more than that of apparent expansion.

2. **Thermal energy always flows from a system at higher temperature to a system at lower temperature.** **True**

3. **According to Charle's law, at constant pressure, the temperature is inversely proportional to volume.** **False**

   According to Charle's law at constant pressure, the temperature is directly proportional to volume.

IV. Match the Following

1.	1) Linear expansion	- a) change in volume	(d)
	2) Superficial expansion	- b) hot body to cold body	(e)
	3) Cubical expansion	- c) 1.381×10^{-23} JK^{-1}	(a)
	4) Heat transformation	- d) change in length	(b)
	5) Boltzmann constant	- e) change in area	(c)

V. Assertion and reason type questions

Mark the correct choice as

a) Both the assertion and the reason are true and the reason is the correct explanation of the assertion.

b) Both the assertion and the reason are true but the reason is not the correct explanation of the assertion.

c) Both assertion and reason false.

d) Assertion is false but the reason is true.

1. **Assertion:** There is no effect on other end when one end of the rod is only heated.
   Reason: Heat always flows from a region of lower temperature to higher temperature of the rod.

Ans : (c) Both assertion and reason false

2. **Assertion:** Gas is highly compressible than solid and liquid
   Reason: Interatomic or intermolecular distance in the gas is comparably high.

Ans : (a) Both the assertion and the reason are true and the reason is the correct explanation of the assertion.

VI. Answer in briefly

1. Define one calorie. ★★

One calorie is defined as the amount of heat energy required to raise the temperature of **1 gram** of water through **1° C.**

2. Distinguish between linear, superficial and cubical expansion. ★

Linear Expansion	Superficial Expansion	Cubical Expansion
When a body is heated or cooled, the **length** of the body changed due to change in its temperature, then the expansion is called as linear expansion.	If there is an increase in the **area** of a solid object due to heating, then the expansion is called as superficial expansion.	If there is an increase in the **volume** of a solid due to heating, then the expansion is called as cubical expansion.
The **ratio** of increase in **length** of the body per **degree** rise in temperature is called as the co-efficient of linear expansion.	The **ratio** of the increase in ratio of the body per **degree rise in temperature** to its unit area is called as co-efficient of superficial expansion.	The **ratio** of the increase in **volume** of the water of the body per **degree** rise in temperature to its unit volume is called as co-efficient of cubical expansion.
This is otherwise called as **longitudinal** expansion.	This is otherwise called as **Areal** expansion.	This is otherwise called as **volumetric** expansion.

3. What is co-efficient of cubical expansion?

- The **ratio** of the increase in **volume** of the body per **degree** rise in temperature to its **unit volume** is called as co-efficient of cubical expansion.
- SI unit – $\mathbf{K^{-1}}$.
- Co - efficient of cubical expansion can be expressed as $\frac{\Delta V}{V_p} = \alpha_V \Delta T$

4. State Boyle's law

When the **temperature** of a gas is kept **constant**, the **volume** of the fixed mass of the gas is **inversely** proportional to its **pressure.**

$$P \propto \frac{1}{V}$$

5. State-the law of volume

Charles's law is otherwise called as the law of volume. It states that when the **pressure** of gas is kept **constant**, the **volume** of the gas is **directly** proportional to the **temperature** of the gas.

$$V \propto T$$

6. Distinguish between ideal gas and real gas. ★★

Ideal gas	Real gas
If the atoms or molecules of a gas **do not interact with each other**, then the gas is said to be ideal gas.	If the molecules or atoms of a gases **interact with each other** with a definite amount of intermolecular or interatomic force of attraction, then the gases are said to be real gases.

7. What is co-efficient of real expansion?

- Co-efficient of real-expansion is defined as the ratio of the **true rise** in the **volume** of the liquid per degree rise in **temperature** to its unit volume.
- Its SI unit is $\mathbf{K^{-1}}$

8. What is co-efficient of apparent expansion?

- Co-efficient of **apparent** expansion is defined as the ratio of the **apparent rise** in the **volume** of the liquid per degree rise in **temperature** to its volume.
- Its SI unit is $\mathbf{K^{-1}}$

VII. Numerical problems:

1. Find the final temperature of a copper rod. Whose area of cross section changes from 10 m^2 to 11 m^2 due to heating. The copper rod is initially kept at 90 K. (Co-efficient of superficial expansion is 0.0021 /K) ★

Solution:

Given:

$$\Delta A = 11 m^2 - 10\ m^2 = 1\ m^2$$

$$T_1 = 90\ K$$

$$\alpha_A = 0.0021/\ K$$

$$T_2 = ?$$

Formula used:

$$\frac{\Delta A}{A_0} = \alpha_A \Delta T$$

$$\frac{\Delta A}{A_0} = \alpha_A \Delta T$$

$$\frac{1m^2}{10m^2} = 0.0021\ [T_2 - 90]$$

$$0.1 = 0.0021\ [T_2 - 90] = \frac{0.1}{0.0021} + 90 = T_2$$

$$\mathbf{T_2 = 137.61\ K}$$

So the final temperature of a copper rod is **137.61 K**

2. Calculate the co-efficient of cubical expansion of a zinc bar. Whose volume is increased 0.25 m^3 from 0.3 m^3 due to the change in its temperature of 50 K.

Solution:

Given:

Change in volume (ΔV) $= 0.25\ m^3$

Original volume (V_0) $= 0.3\ m^3$

Change in Temperature $\Delta T = 50\ K$

$$\alpha_V = ?$$

Formula used:

Co-efficient of cubical expansion

$$\alpha_V = \frac{\Delta V}{V_0} \times \Delta T$$

$$\frac{\Delta V}{V_0} = \alpha_V \Delta T = \frac{0.25}{0.3} = \alpha_V \times 50$$

$$\alpha_V = \frac{0.05}{0.25 \times 50} = 0.0167 K^{-1}$$

Co-efficient of cubical expansion of Zinc bar **0.0167 K**

VIII. Answer in detail

1. Derive the ideal gas equation. ★★★

- The ideal gas equation is an equation, which relates to **all the properties** of an ideal gas.
- An ideal gas obeys **Boyle's law** and **Charles' law** and **Avogadro's law**.
- According to Boyle's law,

  $PV = constant$ -----(1)
- According to Charles's law,

  $V/T = constant$ -----(2)
- According to Avogadro's law,

  $V/n = constant$ -----(3)

  After combining equations (1), (2) and (3), you can get the following equation.

  $\boldsymbol{PV/nT = constant}$ **-----(4)**

  The above relation is called the combined law of gases.
- If you consider a gas, which contains μ moles of the gas, the number of atoms contained will be equal to μ times the Avogadro number, N_A.

  i.e. $n = \mu N_A$. -----(5)

  Using equation (5), equation (4) can be written as

  $PV/ \mu N_A T = \text{constant}$

  The value of the constant in the above equation is taken to be k_B, which is called as **Boltzmann constant (1.38×10^{-23} JK^{-1})**. Hence, we have the following equation:

  $PV/ \mu N_A T = k_B$

  $PV = \mu N_A k_B T$

  Here, $\mu N_A k_B = R$, which is termed as universal gas constant whose value is 8.31 J mol^{-1} K^{-1}.

  $\boldsymbol{PV = RT}$ -------(6)

  Ideal gas equation is also called as *equation of state* because it gives the relation between the state variables and it is used to describe the state of any gas.

2. Explain the experiment of measuring the real and apparent expansion of a liquid with a neat diagram. ★★

Aim:

To measure real and aparent expansion of liquid.

Apparatus Required:

Round bottomed flask, a narrow glass tube with a scale, burner.

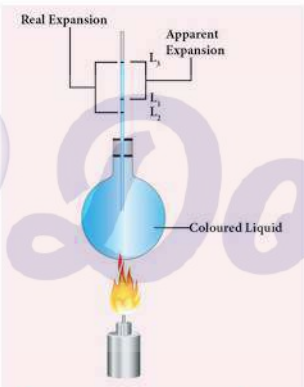
Procedure:

- The **liquid** whose real and apparent expansion is to be determined is poured in a **container** up to a level.

- Mark this level as L_1.
- Now, **heat** the container and the liquid using a burner.
- Initially, the container receives the thermal energy and it **expands**.
- As a result, the **volume** of the liquid appears to have **reduced**.
- Mark this reduced level of liquid as L_2.
- On further **heating**, the thermal energy supplied to the liquid through the container results in the **expansion** of the liquid.
- Hence, the level of liquid rises to L_3.
- Now, the difference between the levels L_1 and L_3 is called as **apparent expansion**.
  Apparent expansion = $L_3 - L_1$.
- The difference between the levels L_2 and L_3 is called **real expansion**.
  Real expansion = $L_3 - L_2$.

Result:

- The real expansion is always more than that of apparent expansion.



Real and apparent expansion of liquid

IX. Higher Order Thinking Skills (HOTS)

1. If you keep ice at 0° C and water at 0°C in either of your hands, in which hand you will feel more chillness? Why?

- 0°C ice is colder than water.
- This can be explained in terms of the latent heat of fusion (336 kJ) which is required to convert ice at 0°C to water at 0°C.
- In simpler terms water at 0°C has higher heat content than ice at the same temperature.
- Thus we conclude ice at 0°C is colder.

Additional Questions

I. Choose the most suitable answer from the given four alternatives and write the option code and corresponding answer:

1. Temperature is the

a) average kinetic energy of the molecules
b) average potential energy of the molecules.
c) total energy of the molecules.
d) none of the above

2. The absolute scale of temperature of a body is ✶

a) 1K
b) 0 K
c) 100 K
d) None

3. Two or more physical system or bodies are said to be in equilibrium

a) if there is a flow of thermal energy between the systems.
b) if there is no net flow of thermal energy between the systems
c) if there may or may not be a flow of thermal energy between the systems.
d) None of the above

4. Unit of heat energy is

a) Kelvin
b) Calorie
c) Celsius
d) Fahrenheit

5. When a body is heated or cooled

a) the mass of the system is also altered
b) the mass of the system is not altered
c) the mass of the system may or may not be altered
d) none of the above

6. For any exchange of heat

a) heat gained by the cold system is equal to the heat lost by the hot system.
b) heat gained by the cold system is more than the heat lost by the system.
c) heat gained by the cold system is lesser than the heat lost by the system.
d) none of the above.

7. One kilo calorie is defined as the amount of heat energy required to rise the temperature of ✶

a) 1 kg through 1°C
b) 1 g through 1°C
c) 1 kg through 100°C
d) 1 g through 100°C

8. When a certain amount of heat energy is given to the substance

a) Temperature of the substance rises
b) The substance may change its state
c) The substance will expand
d) All the above

9. Rise in temperature depends on the

a) nature and mass of the substance
b) nature of the substance only
c) mass of the substance only
d) none of the above

10. The SI unit of co-efficient of linear expansion is

a) K^{-1} b) K
c) mK d) $m^{-1}K^{-1}$

11. The co-efficient of linear expansion is

a) different for different material
b) same for all the metals
c) independent on the nature of the metals
d) different for same metals under different conditions

12. SI unit of co-efficient of real expansion is

a) K^{-1} b) K
c) K^2 c) mK

13. Which of the statements given below is true?

a) The real expansion is always more than that of apparent expansion
b) The real expansion and apparent expansion are equal
c) The real expansion is always lesser than that of apparent expansion
d) None of the above

14. Charles's law is otherwise called as ★

a) law of mass b) law of temperature
c) law of pressure d) law of volume

15. According to Avogadro's law

a) $\frac{V}{T}$ is constant b) PV = a constant
c) $\frac{V}{n}$ = a constant d) Vn = a constant

16. Practically in an ideal gas

a) there is no interaction of molecules
b) the interaction of molecules are weaker
c) the interaction of molecules are stronger
d) the interaction of molecules are either weaker or stronger

17. An ideal gas obeys

a) Boyle's law b) Avogadro's law
c) Charles's law d) All the above

18. The value of Boltzmann's constant is ★ ★

a) 1.38×10^{-23} JK^{-1} b) 13.8×10^{-23} JK^{-1}
c) 1.38×10^{-21} JK^{-1} d) 1.38×10^{-22} JK^{-1}

Ans:

1.	a)	average kinetic energy theory of the molecules	10.	a)	K^{-1}
2.	b)	0 K	11.	a)	different for different material
3.	b)	if there is no net flow of thermal energy between the systems	12.	a)	K^{-1}
4.	b)	calorie	13.	a)	the real expansion is always more than that of apparent expansion
5.	b)	the mass of the system is not altered	14.	d)	law of volume
6.	a)	heat gained by the cold system is equal to the heat lost by the hot system	15.	c)	$\frac{V}{n}$ = a constant
7.	a)	1 kg through 1°C	16.	b)	the interaction of molecules are weaker
8.	d)	All the above	17.	d)	All the above
9.	a)	nature and mass of the substance	18.	a)	1.38×10^{-23} JK^{-1}

II. Fill in the blanks

1. **Temperature is the average _____ of the molecules.**
2. **Absolute temperature is also known as _____.**
3. **Heat is a _____ quantity.**
4. **The _____of a system is not altered when it is heated or cooled.** ✶
5. **The change in dimension due to rise in temperature is called _____ of the object.**
6. **Co-efficient of superficial expansion is _____ for different metals.**
7. **The Co-efficient of cubical expansion of liquid is independent of _____.**
8. **The SI unit of co-efficient of real expansion is _____.**
9. **The real expansion is always _____ than that of apparent expansion.** ✶
10. **Ideal gas equation is also called as _____** ✶

Ans:

1.	Kinetic energy	6.	different
2.	thermodynamic temperature	7.	Temperature
3.	scalar	8.	K^{-1}
4.	mass	9.	more
5.	Thermal expression	10.	Equation of state

III. State whether the following statements are true or false, if false explain why.

1. For any exchange of heat, the heat gained by the cold system is equal to heat lost by the hot system. **True**

2. One calorie is defined as the amount of heat energy required to rise the temperature of 1 kg of water to 1° C. ✱ **False**

   One calorie is defined as the amount of heat energy required to rise the temperature of 1 gram of water to 1°C.

3. At constant temperature and pressure the volume of the gas is directly proportional to number of atoms or molecules present in it. **True**

4. Ideal gases do not obey Boyle's law and Charle's law. **False**

   Ideal gases obey Boyle's law and charle's law.

5. SI unit of temperature is joule. ✱ **False**

   SI unit of temperature is kelvin.

6. The expansion of the liquid apparently observed without considering the expansion of the container is called as real expansion. **False:**

   The expansion of a liquid apparently observed without considering the expansion of the container is called apparent expansion.

7. All forms of matter undergo expansion on heating. **True**

8. In the ideal gas equation PV = RT; R is known as Boltzmann's constant. ✱ **False**

   In the ideal gas equation PV = RT; R is known as Universal gas constant.

IV. Match the Following

I.	1) Boltzmann's constant	-	a) −273° C ✱	(d)
	2) Universal gas constant	-	b) 6.023×10^{23}	(c)
	3) Avogadro number	-	c) 8.315 J $mol^{-1}K^{-1}$	(b)
	4) Zero kelvin	-	d) 1.38×10^{-23} JK^{-1}	(a)
II.	1) Heat energy	-	a) kelvin	(c)
	2) Temperature	-	b) J mol^{-1} K^{-1}	(a)
	3) Co-efficient of linear expansion	-	c) joule	(d)
	4) Universal gas constant	-	d) K^{-1}	(b)
III.	1) Thermodynamic temperature	-	a) longitudinal expansion	(b)
	2) Linear expansion	-	b) absolute temperature	(a)
	3) Cubical expansion	-	c) arial expansion	(d)
	4) Superficial expansion	-	d) volumetric expansion	(c)

V. Assertion and reason type questions

1. **Assertion:** Solids undergo expansion on heating.
   Reason: When a solid is heated, the atoms gain energy and vibrate more vigorously.

Ans: (a) Both the assertion and the reason are true and the reason is the correct explanation of the assertion.

2. **Assertion:** Ideal gas equation is called as equation of state.
   Reason: An ideal gas obeys Boyle's law and Charles's law and Avogadro's law.

Ans: (b) Both the assertion and the reason are true but the reason is not the correct explanation of the assertion.

3. **Assertion:** If two bodies are said to be in thermal equilibrium, then they will be at the same temperature.
   Reason: There will be a transfer of heat energy from the hot body to the cold body until a thermal equilibrium is established between them

Ans: (a) Both the assertion and the reason are true and the reason is the correct explanation of the assertion.

VI. Answer in briefly

1. Define temperature. ✶

Temperature is defined as the **degree of hotness** of a body. It is also defined as the property which determines whether a body is in **equilibrium or not** with the surroundings.

2. Define absolute scale of temperature. (or) Define thermodynamic temperature.

The temperature measured in relation to **absolute zero using** the kelvin scale is known as absolute temperature.

3. Define thermal equilibrium.

Two or more physical systems or bodies are said to be in thermal equilibrium if there is **no net flow of thermal energy** between the systems.

4. Define thermal energy.

Thermal energy is a form of energy which is transferred between any two bodies due to the **difference** in their **temperatures**.

5. What is meant by heating?

The process in which **heat energy flows** from a body at a higher temperature to another object at lower temperature is known as heating.

6. Define kilo calorie. ✶

One kilo calorie is defined as the amount of heat energy required to rise the temperature of **1 kilogram** of water through **1°C.**

7. What are the effects of heat energy? ✶

- The temperature of the substance rises.
- The substance may change its state from solid to liquid or from liquid to gas.
- The substance will expand when heated.

8. What do you mean by thermal expansion of the object?

The **change in dimension** due to **rise in temperature** is called thermal expansion of the object.

9. Define co-efficient of linear expansion. Give its unit. ★

- The **ratio** of increase in **length** of the body per **degree** rise in temperature to its **length** is called as the co-efficient of liner expansion.
- It's unit is $\mathbf{K^{-1}}$.
- It can be expressed as, $\frac{\Delta L}{L_o} = \alpha_L \Delta T$

10. Define co-efficient of superficial expansion. Give its unit.

- The **ratio** of increase in **area** of the body per **degree** rise in temperature to its **unit area** is called as the co-efficient of superficial expansion.
- It's unit is $\mathbf{K^{-1}}$.
- It can be expressed as, $\frac{\Delta A}{A_o} = \alpha_A \Delta T$

11. What do you mean by real expansion of the liquid?

If a liquid is heated directly **without using any container,** then the expansion that you observe is termed as real expansion of the liquid.

12. What do you mean by apparent expansion of the liquid?

The expansion of a liquid apparently observed **without considering the expansion** of the container is called the apparent expansion of the liquid.

13. What are the three fundamental laws of gases?

- Boyle's law
- Charles's law
- Avogadro's law.

14. State Avogadro's law. ★★

Avogadro's law states that at constant pressure and temperature, the **volume of a gas** is **directly proportional to number of atoms or molecules** present in it.

15. What do you mean by Avogadro's number?

- It is the **total number of atoms per mole** of the substance.
- It is equal to **6.023×10^{23}/mole.**

VII. Numerical problems:

1. A steel is 40 cm long at 20°C. The co-efficient of linear expansion for steel is 12×10^{-6} / °C. find the increase in length and the final length of the steel at 70° C

Solution:

Given

Original length = 40 cm (L_1)

Change in temperature (ΔT) = 70° – 20° C = 50° C

Co-efficient of linear Expansion $\alpha_L = 12\times 10^{-6}$. C^{-1}

ΔL = ?

L_2 = ?

Formula used:

Increase in length

$\Delta L = L_1 \alpha_L \Delta T$

$$\frac{\Delta L}{L} = \alpha_L \Delta T$$

Increase in length $(\Delta L) = L_1 \alpha_L \Delta T$

$= 40 \times 12 \times 10^{-6} \times 50$

$= 240 \times 10^2 \times 10^{-6} = 24 \times 10^{-3}$ cm

$\Delta L = 0.024$ cm

Final length $L_2 = L_1 + \Delta L = 40 + 0.024 = 40.024$ cm

$L_2 =$ 40.024 cm

2. An iron rod heated from 30° C to 80° C. The final length of iron is 115 cm and the co-efficient of linear expansion is 3×10^{-3} °C^{-1}. What is the original length and the change in length of the iron?

Solution

Given:

Formula used:

Change in length

$\Delta L = L_2 - L_1$

$\Delta T = 80° - 30°$ C $= 50°$ C

$L_2 = 115 \times 10^{-2}$ m

$\alpha_L = 3 \times 10^{-3}$ $^0C^{-1}$

$L_1 = ?$

$L_2 = \Delta L + L_1$

$= L_1 \alpha \Delta T + L_1$

$= L_1 (\alpha \Delta T + 1)$

$115 = L_1 (1 + 3 \times 10^{-3} \times 50)$

$115 = L_1 (1 + 0.15)$

$115 = L_1 (1.15)$

$$L_1 = \frac{115}{1.15} = 100 \text{ cm}$$

$L_1 = 100$ cm

So the original length was 100 cm

3. At 30° C the volume of an Aluminium sphere is 30 cm^3. The co-efficient of linear expansion is 24×10^{-6} °C^{-1}. If the final volume is 30.5 cm^3. What is the final temperature of the aluminium sphere?

Solution:

Given:

Formula used:

Volume change

$\Delta V = \beta (V_1) (T_2 - T_1)$

$\alpha = 24 \times 10^{-6}$ °C^{-1}

$\alpha_V = 3\alpha_A = 3 \times 24 \times 10^{-6} = 72 \times 10^{-6}$

$T_1 = 30°C$, $V_1 = 30 cm^3$, $V_2 = 30.5$ cm^3

$\Delta V = 30.5 - 30 = 0.5$ cm^3

$T_2 = ?$

$$\frac{\Delta V}{V} = \alpha_V \Delta T$$

$$\Delta V = \beta (V_1) (T_2 - T_1)$$

$$0.5 = 72\times 10^{-6} \times 30\times (T_2 - 30)$$

$$0.5 = 2160\times 10^{-6} (T_2 - 30)$$

$$(T_2 - 30) = \frac{2160}{0.5} \times 10^{-6}$$

$$T_2 = 230 + 30 = 260^\circ C$$

$$\mathbf{T_2 = 260^\circ C}$$

4. At 30° C, the area of a sheet of aluminium is 40 cm² and the co-efficient of linear expansion is 24× 10^{-6} /°C. Determine the final temperature if the final area is 40.2 cm² ✶

Formula used:

Temperature change

$\Delta T = \alpha_A A_1 (T_2 - T_1)$

Solution:

Given:

$$T_1 = 30^\circ, \alpha_L = 24\times 10^{-6} {}^\circ C^{-1}$$

$$\alpha_A = 2a = 2\times 24\times 10^{-6} = 48\times 10^{-6} {}^\circ C^{-1}$$

$$A_1 = 40 \text{ cm}^2, A_2 = 40.2 \text{ cm}^2, \Delta A = 0.2 \text{ cm}^2$$

$$\Delta A = \alpha_A A_1$$

$$\Delta T = \alpha_A A_1 (T_2 - T_1)$$

$$0.2 = 48\times 10^{-6} \times 40\times (T_2 - 30)$$

$$0.2 = 1920\times 10^{-6} (T_2 - 30)$$

$$T_2 - 30 = \frac{1920}{0.2} = 10^{-6}, T_2 = 100 + 30 = 130^\circ C$$

The final temperature = 130° C

5. A gas occupies 1.56L at 1.00 atm. What will be the volume of this gas if the pressure becomes 3.00 atm

Solution

Given:

$$\text{Volume} = 1.56 \text{ Litre}$$

$$(1.56\text{L})(1 \text{ atm}) = 3 \text{ atm} \times x$$

$$x = \frac{1.56}{3} = 0.52 \text{ L}$$

$$\mathbf{x = 0.52 \text{ L}}$$

6. 600 mL of air is at 20° C. What is the volume at 60° C ?

Solution

Given:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad \begin{bmatrix} 20^\circ C = 293K \\ 60^\circ C = 333K \end{bmatrix}$$

$$\frac{600mL}{293K} = \frac{X}{333K}$$

$$X = 682 \text{ mL}$$

VIII. Answer in detail

1. What is meant by heat energy? What are the characteristics features of heat energy transfer?

Heat energy:

- When a hot object is in contact with another cold object, a form of **energy flows** from **the hot object to the cold object,** which is known as thermal energy.
- Thus, thermal energy is a form of energy which is **transferred between any two bodies** due to the difference in their temperatures.
- Thermal energy is also known as **'heat energy'** or simply **'heat'.**

Characteristics features of heat energy transfer:

- Heat always flows from a system at **higher** temperature to a system at **lower** temperature.
- The mass of a system is **not altered** when it is heated or cooled.
- For any exchange of heat, the **heat gained** by the cold system is equal to **heat lost** by the hot system.
- **Heat gained = Heat lost**

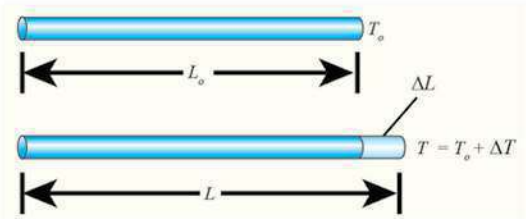
2. Explain the different types of expansion in solids. ★

The different types of expansion of solid are listed and explained below

- Linear expansion
- Superficial expansion
- Cubical expansion

Linear expansion:

- When a body is heated or cooled, the **length of the body changes** due to change in its temperature.
- Then the expansion is said to be linear or longitudinal expansion.
- The **ratio** of increase in **length** of the body per **degree** rise in temperature to its **unit length** is called as the co-efficient of linear expansion.
- The SI unit of Co-efficient of Linear expansion is $\mathbf{K^{-1}}$.
- The value of co-efficient of linear expansion is different for different materials.



Linear expansion

- The equation relating to the change in length and the change in temperature of a body is given below:

$$\frac{\Delta L}{L_o} = \alpha_L \Delta T$$

ΔL - Change in length (Final length- Original length)

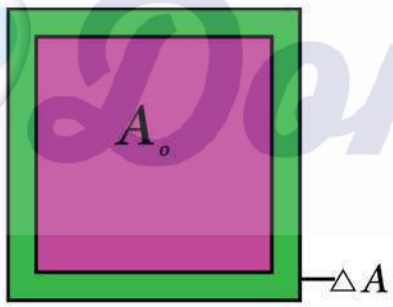
L_0 - Original length

ΔT - Change in temperature (Final temperature - Initial temperature)

α_L - Co-efficient of linear expansion.

Superficial expansion:

- If there is an **increase in the area of a solid object** due to heating, then the expansion is called superficial or a real expansion.
- Superficial expansion is determined in terms of co-efficient of superficial expansion.
- The **ratio** of increase in **area** of the body per degree rise in temperature to its **unit area** is called as co-efficient of superficial expansion.
- Co-efficient of superficial expansion is different for different materials.
- The SI unit of Co-efficient of superficial expansion is $\mathbf{K^{-1}}$.



Superficial expansion

- The equation relating to the change in area and the change in temperature is given below:

$$\frac{\Delta A}{A_o} = \alpha_A \Delta T$$

ΔA - Change in area (Final area - Initial area)

A_o - Original area

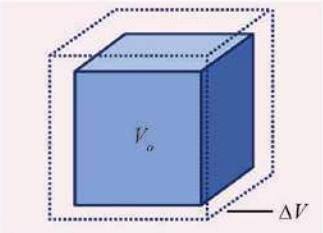
ΔT - Change in temperature (Final temperature - Initial temperature)

α_A - Co-efficient of superficial expansion.

Cubical expansion:

- If there is an **increase in the volume** of a solid body due to heating, then the expansion is called cubical or volumetric expansion.
- As in the cases of linear and areal expansion, cubical expansion is also expressed in terms of co-efficient of cubical expansion.
- The **ratio** of increase in **volume** of the body per **degree** rise in temperature to its **unit | volume** is called as co-efficient of cubical expansion.

- This is also measured in K^{-1}.



Cubical expansion

- The equation relating to the change in volume and the change in temperature is given below:

$$\frac{\Delta V}{V_o} = \alpha_v \Delta T$$

ΔV - Change in volume(Final volume - Initial volume)

V_o - Original volume

ΔT - Change in temperature (Final temperature - Initial temperature)

α_V - Co-efficient of cubical expansion.

- Different materials possess different co-efficient of cubical expansion.

3. Explain three fundamental laws of gases. ★★

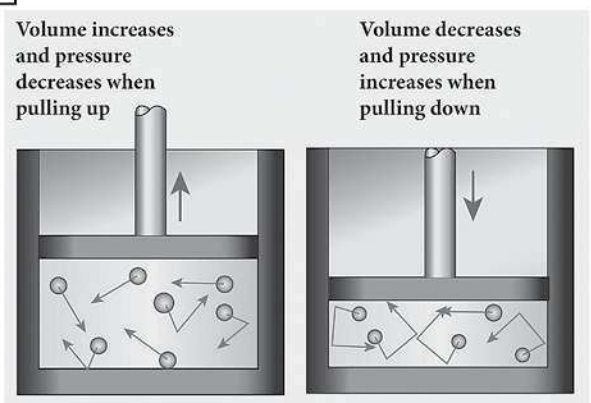
The three fundamental laws which connect the relation between pressure, volume and temperature are as follows

- Boyle's Law
- Charles's law
- Avogadro's law

Boyle's law:

When the **temperature** of a gas is kept **constant**, the **volume** of a fixed mass of gas is **inversely** proportional to its **pressure**. This is shown in Figure

$$P \propto 1 / V$$



Variation of volume with pressure

- In other words, for an invariable mass of a perfect gas, at constant temperature, the product of its pressure and volume is a constant.

(i.e) **PV = constant**

Charle's law (The law of volume)

Charle's law was formulated by a **French scientist Jacques Charles**. According to this law, When the **pressure** of gas is kept **constant**, the **volume** of a gas is **directly** proportional to the **temperature** of the gas.

$$\boxed{V \propto T}$$

$$\text{or } \frac{V}{T} = \text{constant}$$

Avogadro's law:

Avogadro's law states that at **constant pressure and temperature**, the **volume** of a gas is **directly** proportional to **number of atoms or molecules** present in it.

$$\text{i.e.} \quad \boxed{V \propto n}$$

$$\text{(or)} \quad \frac{V}{n} = \text{constant}$$

- Avogadro's number (N_A) is the total number of atoms per mole of the substance.
- It is equal to **6.023×10^{23} /mol.**

IX. Higher Order Thinking Skills (HOTS)

1. An iron ball at 40° C is transferred to a mug containing water at a temperature of 40° C, in which direction will the heat flow?

Heat will not flow. Because, the iron ball and water are at same temperature.

2. Wet clothes dry in summer faster. Why?

Transfer of heat energy from environment to wet clothes till thermal equillibrium is established.

Unit Test - 3

Thermal Physics

Time : 1 hr | Marks : 30

I. Choose the most suitable answer and write the code with the corresponding answer. 5 × 1 = 5

1. The value of universal gas constant
   a) 3.81 $mol^{-1} K^{-1}$ b) 8.03 $mol^{-1} K^{-1}$ c) 1.38 $mol^{-1} K^{-1}$ d) 8.31 J $mol^{-1} K^{-1}$
2. Temperature is the average _____ of the molecules of a substance
   a) difference in K.E and P.E b) sum of P.E and K.E
   c) difference in T.E and P.E d) difference in K.E and T.E
3. Charles's law is otherwise called as
   a) law of mass b) law of temperature
   c) law of pressure d) law of volume
4. The value of Boltzmann's constant is
   a) 1.38×10^{-23} JK^{-1} b) 13.8×10^{-23} JK^{-1}
   c) 1.38×10^{-21} JK^{-1} d) 1.38×10^{-22} JK^{-1}
5. a) Both the assertion and the reason are true and the reason is the correct explanation of the assertion.
   b) Both the assertion and the reason are true but the reason is not the correct explanation of the assertion.
   c) Assertion is true but the reason is false.
   d) Assertion is false but the reason is true.

   Assertion: There is no effects on other end when one end of the rod is only heated.

   Reason: Heat always flows from a region of lower temperature to higher temperature of the rod.

II. Answer the following questions in one or two lines. 5 × 2 = 10

1. Define one calorie.
2. State Boyle's law.
3. What are the effects of heat energy?
4. State Avogadro's law.
5. Why do the substance expand?

III. Answer the fllowing questions in brief: 2 × 4 = 8

1. Distinguish between linear, areal and cubical expansion.
2. i) State Avogadro's law.
   ii) What do you mean by real expansion of the liquid?

IV. Answer the fllowing questions in detail: 1 × 7 = 7

1. i) Derive the ideal gas equation?
   ii) Define kilo calorie.