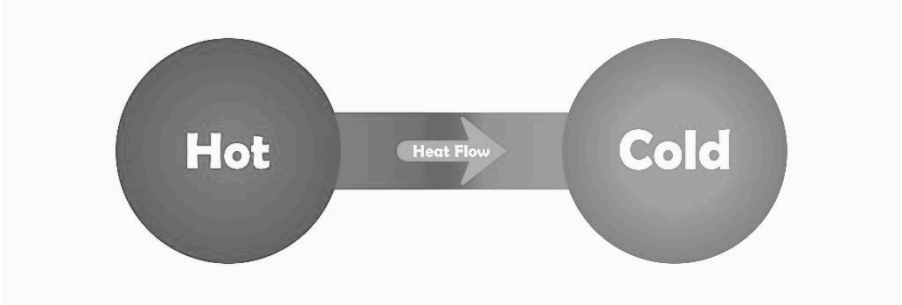


HEAT

Concepts Covered

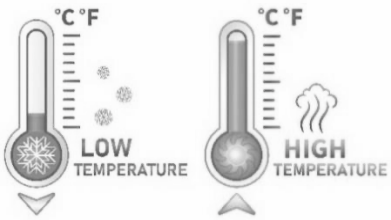
- Different Scales of Temperature
- Role of Temperature in Transfer of Heat Energy
- Unit of Heat Energy
- Calorimetry, Specific Heat

Introduction

In our day-to-day life, we feel a cool sensation when we touch a piece of ice. Similarly, we feel a hot sensation when we accidentally touch a vessel kept on a stove. The feeling of coldness or hotness is due to the relative flow of heat between our body and the object being touched. In the above example, heat flows into our body when we touch a hot body, while heat flows out of our body when we touch a cold body.

Temperature

When we touch two bodies, it is possible for us to determine which body is relatively hotter. However, it is not possible for us to tell exactly how hot a body is. The measure of hotness or coldness of a body is called temperature. When a body is heated, generally its temperature rises. Thus, heat is the cause, while temperature is an effect.



Measurement of Temperature

The instrument used for the measurement of temperature is called a thermometer.

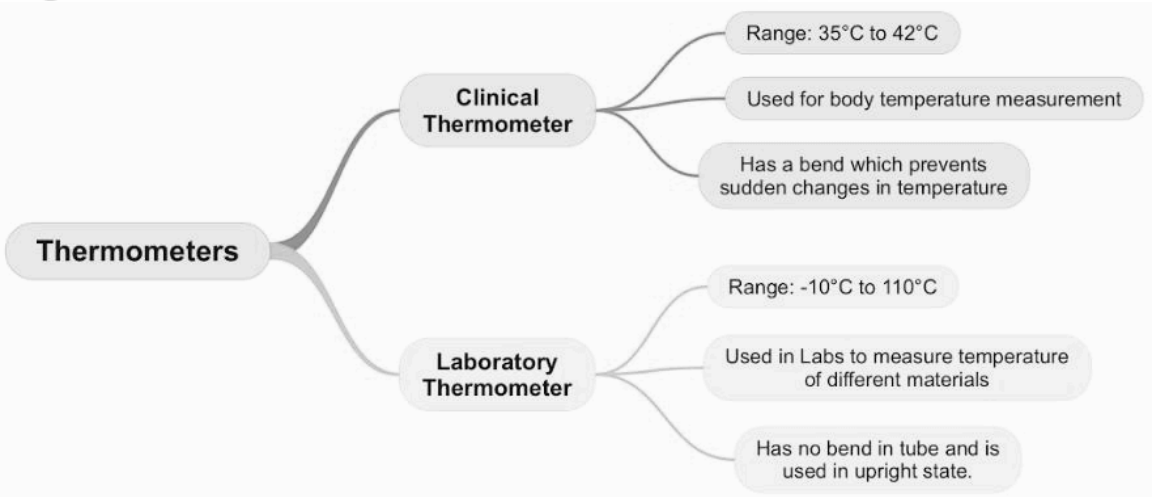
- **Clinical Thermometer**
  The thermometer that measures our body temperature is called a clinical thermometer. A clinical thermometer consists of a long, narrow, uniform glass tube. It has a bulb at one end. This bulb contains mercury. When we look at the bulb from outside, a shining mercury thread can be seen. Its measurement range is 35°C to 42°C, as normal body temperature lies in it.

- **Laboratory Thermometer**
  A Laboratory thermometer is used to measure the temperature of general objects. The range of the laboratory thermometer is between -10 °C to 110 °C. Its range is larger than a clinical thermometer because it is used in many applications.

DID you KNOW

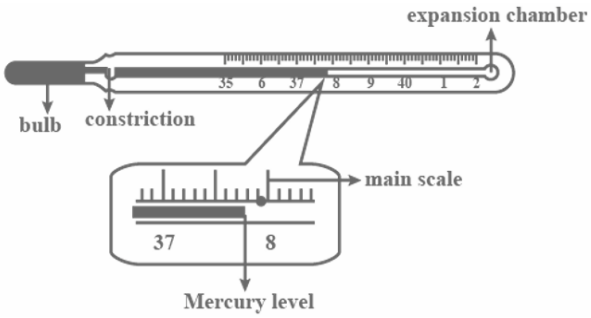
Heat is a form of energy that is created by the movement of molecules. When an object is heated, the molecules move faster. When cooled, the molecules move slower.

Mind Map



Reading a Thermometer

The temperature of substances is measured using a thermometer, and the level of liquid in the thermometer tube gives the reading on a marked scale.



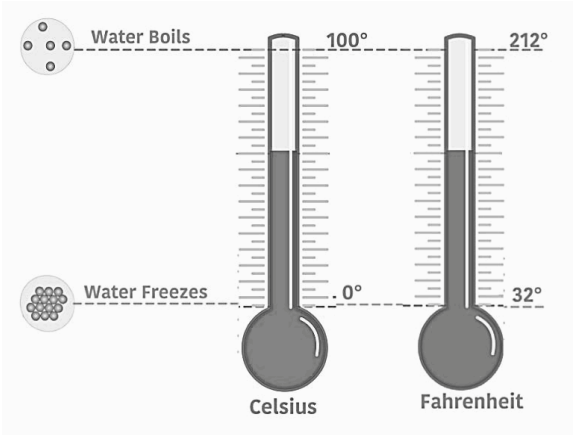
Precautions to be Taken While Using a Clinical Thermometer

- A thermometer should be washed before and after use, preferably with an antiseptic solution.
- Ensure that before use, the mercury level is below $35°C$.
- Read the thermometer keeping the level of mercury along the line of sight.
- Handle the thermometer with care as it is fragile.
- Do not hold the thermometer by the bulb while reading it.

Different Scales of Temperature

(A) Celsius or Centigrade Scale

The centigrade scale is divided into degrees based on dividing the temperature between the points at which water freezes and boils into 100 equal gradients or degrees. The word centigrade comes from "centi-" which means 100 and "grade" which stands for gradients.This scale was introduced by the Swedish astronomer, Anders Celsius, and is known after his name. On this scale, 0°C represents the melting point of ice and 100°C represents the boiling point of water. Each division on this scale is called one-degree centigrade or one degree Celsius and is written as °C.



(B) Fahrenheit Scale

The scale was introduced by Daniel Gabriel Fahrenheit. On this scale, 32°F represents the melting point of ice and 212°F repesents the boiling point of water.The length between the standard points is divided into 180 equal parts. Each division on this scale is called 1°F. This scale is widely used for meteorological and clinical purposes.

Relation between $°C$ & $°F$

$$\frac{C-0}{5}=\frac{F-32}{9}$$

(C) Kelvin Scale

This is the SI scale of temperature measurement. The lowest temperature possible in nature is taken as zero in this scale.

Zero Kelvin (–273°C) is called absolute zero. The symbol for this scale is K.

Characteristics of Kelvin Scale

(i) Since 0 Kelvin is the lowest temperature, there cannot be any temperature below it.

(ii) Rise in temperature in Kelvin = Rise in temperature in degree Celsius.

Relation between °C & K

K = °C + 273

Example:

(1) Convert 27°C into kelvin.
Answer: K = °C + 273
K = 27 + 273 = 300 K

(2) Convert 140°F to Celsius.
Solution: We know that the formula for converting Fahrenheit to Celsius is °C = $\frac{[(°F-32)\times 5]}{9}$
°C = $\frac{[(140-32)\times 5]}{9} = \frac{108\times 5}{9} = \frac{540}{9}$ = 60
Therefore, 140°F = 60°C.

(3) Convert 35°C to Fahrenheit.
Solution: We know that the formula for converting Celsius to Fahrenheit is °F = $\frac{°C\times 9}{5}$ + 32
°F = $\frac{35\times 9}{5}$ + 32 = 63 + 32 = 95
Therefore, 35°C = 95°F.

(4) At which temperature do both Celsius and Fahrenheit scales show the same reading?
Solution: The relation between °C and °F is $\frac{C-0}{5} = \frac{F-32}{9}$
when $F = C$
$\therefore\ C - \frac{9}{5}C = 32 \quad \therefore\ -\frac{4}{5}C = 32$
$\therefore\ C = -40°C \quad \therefore\ T = -40°C$
$\therefore$ At $-40°C$, both the Celsius and Fahrenheit scales show the same reading.

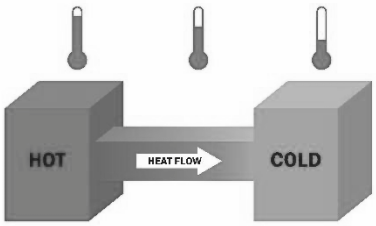
Check Your Concept - 1

(i) Working of a liquid thermometer depends on the fact that
(A) substances expand on heating.
(B) substances contract on heating.
(C) substances are not affected by heating.
(D) substances first expand and later contract on heating.
(ii) Convert 348K to the Fahrenheit scale.
(iii) Convert 14°F to the Celsius scale.
(iv) Convert 60°C to the Fahrenheit scale.

Role of Temperature in Transfer of Heat Energy

When two bodies at different temperatures are brought into contact, the heat energy always flows from a body at a higher temperature to the body at a lower temperature until the temperature equalizes. Thus, it determines the direction of the flow of heat energy.

Heat
Heat is defined as the energy that flows from one body to another because of the temperature difference.The quantity of heat is represented by Q.



Unit of Heat
Heat energy is measured in calories or Joules.
The quantity of heat energy required to raise the temperature of 1 g of pure water by 1°C (14.5 °C to 15.5°C) is called one calorie.
1 calorie = 4.186 joules ≃ 4.2 joules
Note: Symbol used for joule is J and for calorie is cal.

Example:

(1) A body was supplied with 6300 joules of heat. Express this amount in kilocalories.

Solution: Quantity of heat in joules $= \mathbf{6300\ J}$

We know that

$$\mathbf{1cal = 4.2\ J \Rightarrow 1\ J = \frac{1}{4.2} cal}$$

$$\therefore \mathbf{6300\ J = 6300 \times \frac{1}{4.2} = 1500\ cal = 1.5\ kcal.}$$

(2) Convert 600 calories into joule and kilojoule.

Solution: We know, 1 cal = 4.2 joules

So 600 cal = 2520 joules = 2.52 kilojoules.

(3) Convert 1.68 kilojoules into joule and calorie.

Solution: 1kJ = 1000 J

So, 1.68 kJ = 1680 J

We know, 1 cal = 4.2 joules

So, 1 joule = $\frac{1}{4.2}$ cal

$\therefore$ 1680 joule = $\frac{1680}{4.2}$ cal = 400 cal.

(4) Convert 5040 joules into kilocalorie.

Solution: We know, 1 cal = 4.2 joules

So, 1 joule = $\frac{1}{4.2}$ cal

$\therefore$ 5040 J = $\frac{5040}{4.2}$ cal = 1200 cal = 1.2 kcal.

Check Your Concept - 2

(i) Convert 8.4 joules into calories.

(ii) Convert 4 calories into joules

(iii) Convert 150 calories into joules and kilojoules.

Calorimetry

The branch of physics which deals with the measurement of heat energy is called calorimetry. It is evident that heat always flows from a body at a higher temperature to a body at a lower temperature till the bodies attain the same temperature (equilibrium temperature). At equilibrium temperature, there is no flow of energy between two bodies. The quantity of heat is measured in calories. In SI system, it is measured in joule.

Definition of Calorie

One calorie is the quantity of heat energy required to raise the temperature of one gram of water by 1ºC. The bigger units of heat are kilocalorie (kcal) and kilojoule (kJ).

Relation between units of heat:

(i) 1 calorie = 4.186 joule = 4.2 J

(ii) 1 J = $\mathbf{10^7}$ erg

(iii) 1 kcal = 1000 cal

(iv) 1 kJ = 1000 J

Principle of Calorimetry

When two bodies having different temperatures are brought into contact with each other, heat is transferred from the body at the higher temperature to the body at a lower temperature, till thermal equilibrium is attained. i.e.,

Heat lost by the body at higher temperature = Heat gained by the body at lower temperature.

Heat Required to Change Temperature

When heat is supplied to a body to change its temperature, the heat required is proportional to the mass of the body and the change in its temperature i.e., $Q \propto m$

$Q \propto \Delta T$

Hence, $Q \propto m\Delta T$ or $Q = ms\Delta T$

Where the constant 's' is called the specific heat of the body. The value of 's' depends on the nature of material.

Specific Heat (s)

The amount of heat required to raise the temperature of the unit mass of a substance by 1 ºC is called specific heat. Mathematically,

$$\text{Specific heat} = \frac{\text{Quantity of heat}}{\text{Mass of the substance} \times \text{Change in temperature}}$$

$$s = \frac{Q}{m\Delta t}$$

Units of Specific Heat:

SI unit is $\mathbf{Jkg^{-1}\ K^{-1}}$.

$\mathbf{CGS}$ unit is cal $\mathbf{g^{-1}(\ ^{\circ}C^{-1})}$.

Advantages of High Specific Heat of Water:

Due to high specific heat of water,
(A) it is used as a coolant in radiators.
(B) formation of land and sea breeze occurs.
(C) it is used for fomentation to relax the body.

Example:

$5\ g$ of hot water at $40^{\circ}C$ is kept in the open air till its temperature falls to $35^{\circ}C$. Calculate the heat energy lost to the surroundings by the water. (Given, the specific heat of water $= 1\ calg^{-1}\ ^{\circ}C^{-1}$).

Solution: Mass of water, $m = 5\ g$
Specific heat of water, $s = 1\ calg^{-1}\ ^{\circ}C^{-1}$
Initial temperature $t_1 = 40^{\circ}C$
inal temperature $t_2 = 35^{\circ}C$
Change in temperature, $\Delta t = 40 - 35 = 5^{\circ}C$
heat, $Q = ?$
We know that
$Q = ms\Delta T = 5 \times 1 \times 5 = 25\ cal$
$\therefore$ The heat lost is $25\ cal$.

Check Your Concept - 2

(i) Water at 50°C loses 50 calories of heat to the surroundings and its temperature falls to 30°C. Calculate the mass of water.

(ii) How much heat is required to raise the temperature of 100 g of water from $5^{\circ}C$ to $95^{\circ}C$?

Solved Examples

(1) What are the different units to measure temperature? Mention the freezing point and boiling point of water in terms of those units.

Answer: Different units of temperature are:
Fahrenheit
Boiling point – 212°F
Freezing point – 32°F
Celsius
Boiling point – 100°C
Freezing point – 0°C
Kelvin
Boiling point – 373K
Freezing point – 273 K

(2) If $0.5\ \mathrm{calg^{-1}\ {}^{\circ}C^{-1}}$ is the specific heat capacity of a substance of mass $50\ \mathrm{g}$, calculate the amount of heat energy required to change the temperature of a substance from $-5^{\circ}\mathrm{C}$ to $10^{\circ}\mathrm{C}$.

(A) $250\mathrm{cal}$ **(B)** $125\mathrm{cal}$
(C) $375\mathrm{cal}$ **(D)** $500\mathrm{cal}$

Solution: (C)

$\mathrm{Q} = \mathrm{ms\Delta t} = 50 \times 0.5 \times (10 - (-5) = 25(15) = 375\mathrm{cal}$.

Hence, the correct option is (C).

(3) Which of the temperatures given below cannot be measured using a clinical thermometer?

(A) $36^{\circ}\mathrm{C}$ **(B)** $38^{\circ}\mathrm{C}$
(C) $40^{\circ}\mathrm{C}$ **(D)** $31^{\circ}\mathrm{C}$

Answer: (D)

$31^{\circ}\mathrm{C}$ cannot be measured by a clinical thermometer.

(4) The amount of heat absorbed by a substance of mass $100\ \mathrm{g}$ when its temperature is increased from $10^{\circ}\mathrm{C}$ to $20^{\circ}\mathrm{C}$ is 1000 cal. The specific heat capacity of the substance is cal $\mathrm{g^{-1}\ {}^{\circ}C^{-1}}$.

Solution: $\mathrm{Q} = \mathrm{ms\Delta t}$

$= 1000 = 100 \times \mathrm{s} \times (20 - 10)$

$\mathrm{s} = \frac{10}{10} = 1\mathrm{calg^{-1}\ {}^{\circ}c^{-1}}$

Exercise

FILL IN THE BLANKS

(1) The range of a laboratory thermometer is _____.
(2) The heat needed to convert 10 g of water at 10°C to 80°C is _____ Calories.
(3) 50°F = _____°C.
(4) Boiling point of water in kelvin scale is _____.
(5) The _____ in a clinical thermometer prevents backflow of the mercury into the bulb.
(6) The temperature of the boiling water is measured with _____ thermometer.

TRUE OR FALSE

(1) Water boils at 212°F.
(2) A laboratory thermometer has a kink in the capillary tube.

OBJECTIVE TYPE QUESTIONS

(1) A body was supplied 12600 joules of heat. Express this amount in kilocalories.
(A) 3.4 kcal (B) 3.0 kcal
(C) 5.8 kcal (D) 5.0 kcal

(2) The difference between the lower fixed point and the upper fixed point is divided into _____parts on a Celsius scale.
(A) 100 (B) 273
(C) 180 (D) 50

(3) 1 calorie = _____.
(A) Amount of heat energy required to transform 1 kg of ice into the water at 0°C
(B) Amount of heat energy required to raise the temperature of 1 kg of water through 1°C
(C) Amount of heat required to raise the temperature of 1 g of water through 1°C
(D) Quantity of work done at atmospheric pressure

(4) To convert Celsius temperature into kelvin temperature, the formula is:
(A) $\mathbf{K = {}^{\circ}C + 273}$ (B) $\mathbf{{}^{\circ}C = K + 273}$
(C) $\mathbf{{}^{\circ}C + K = 273}$ (D) None of these

Answer Key

CHECK YOUR CONCEPTS

(1) **(i)** (A) **(ii)** 167°F
(iii) -10°C **(iv)** 140°F
(2) **(i)** 2 calories **(ii)** 16.8 joules **(iii)** 630 joules, 0.63 kilojoules
(3) **(i)** 2.5 g **(ii)** 9 kcal

FILL IN THE BLANKS

(1) -10°C to 110°C.
(2) 700
(3) 10
(4) **373 K**
(5) kink
(6) laboratory

TRUE OR FALSE

(1) True
(2) False

OBJECTIVE TYPE QUESTIONS

(1) (B)
(2) (A)
(3) (C)
(4) (A)