# Ratna Sagar

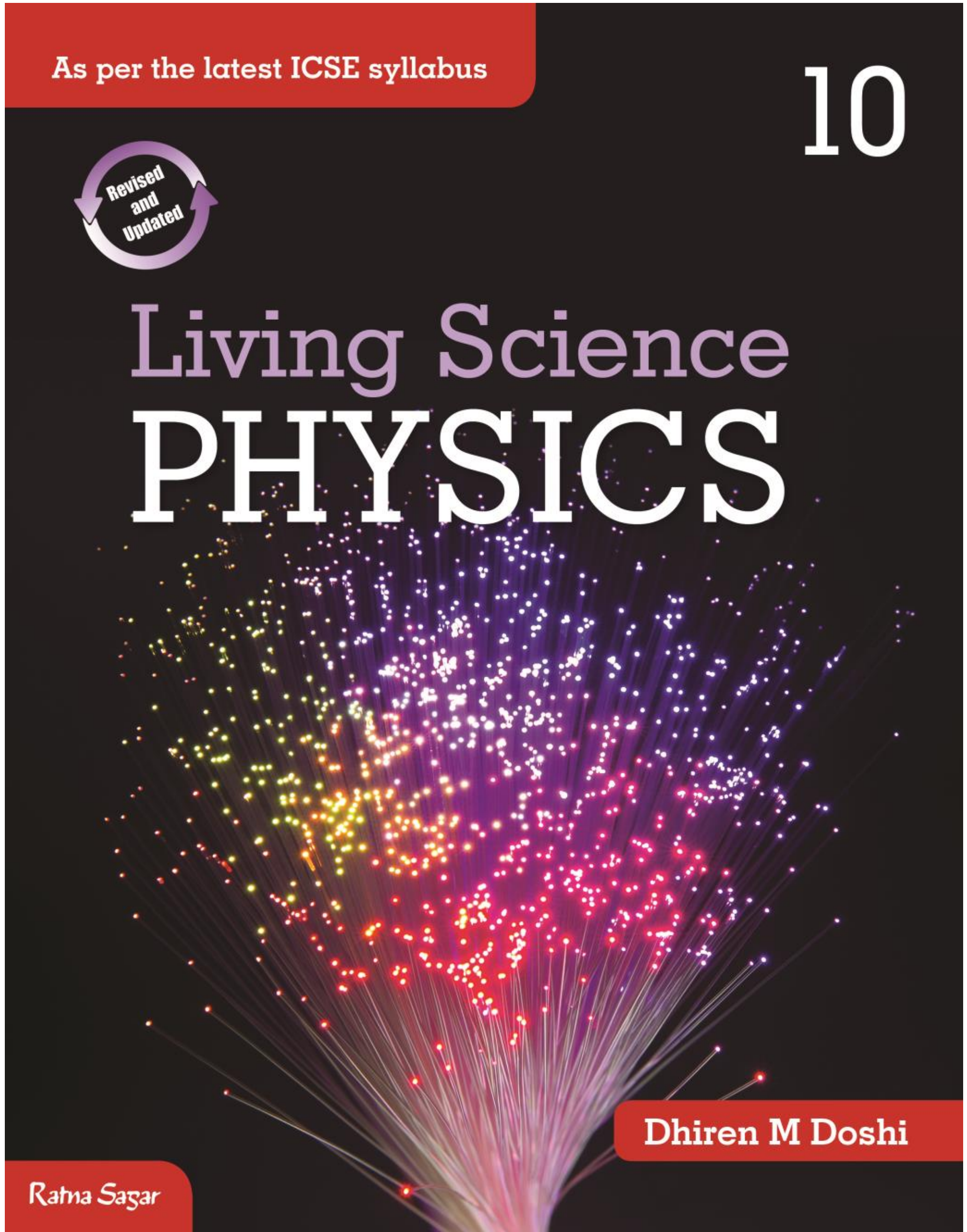
RATNA SAGAR | PRIMUS | BYWORD | E-LIVE

Education, Our Mission

# ICSE
# Living Science
# Physics

## Class 10

## Chapter-11 Calorimetry and Latent Heat


As per the latest ICSE syllabus
10
Revised and Updated
Living Science
PHYSICS
Dhiren M Doshi
Ratna Sagar

## LEARNING OBJECTIVES

**Concept of Heat and Temperature**

**Specific Heat Capacity or Specific Heat**

- ❖Heat capacity or thermal capacity
- ❖Relation between heat capacity and specific heat
- ❖Advantages of high specific heat capacity of water

**Calorimeter**

- ❖Principle of calorimetry
- ❖Measurement of specific heat capacity of a liquid by Regnault's apparatus

**Change of Phase (State)**

- ❖Melting and freezing
- ❖Boiling and condensation
- ❖Sublimation

**Heating Curve**

- ❖Heating curve of water

**Latent Heat**

- ❖Specific latent heat of fusion
- ❖ Latent heat of fusion on the basis of kinetic theory
- ❖ Natural consequences of latent heat of fusion of ice
- ❖ Specific latent heat of vaporisation

**Consequences of High Latent Heat of Vaporisation of Water**

## Concept of Heat and Temperature

Heat is a form of energy called thermal energy possessed by a body on account of the random motion of its molecules. According to the kinetic molecular theory, the temperature of a body is a measure of the average kinetic energy of that body.

Temperature is the degree of hotness (or coldness) of a substance. The heat energy always flows from a body at higher temperature to a body at lower temperature. The heat keeps on flowing until both the bodies attain the same temperature. Temperature determines the direction of heat flow. An experimental technique for the quantitative measurement of heat exchange is called calorimetry.

### Units of heat

The SI unit of all kinds of energy is **joule** ( J). So heat also being thermal energy, its SI unit is joule ( J). The bigger unit used is called kilojoule (kJ).
1 kilojoule = 1000 joules ∴ 1 kJ = 1000 J

The practical unit of heat energy is **calorie** (cal).
One calorie of heat is the quantity of heat energy required to raise the temperature of one gram of pure water from 14.5 °C to 15.5 °C.

1 calorie = 4.186 joules = 4.2 J (nearly)

## Specific Heat Capacity or Specific Heat

The specific heat of a substance may be defined as the amount of heat required to raise the temperature of unit mass of the substance through unit degree. The value of specific heat ($C$) will depend upon the nature of the substance and will obviously be different for different substances.

We know $\Delta Q = C \cdot m \cdot \Delta T$ or $C = \Delta Q / m \Delta T$

In SI system, heat is measured in joules (J), mass in kilograms (kg) and temperature in degrees (either $^\circ$C or K). So, the SI unit of specific heat ($C$) is joules per kilogram per degree Celsius (J $kg^{-1}$ $^\circ C^{-1}$) or joules per kilogram per kelvin (J $kg^{-1}$ $K^{-1}$).

## Heat capacity or thermal capacity

Heat capacity of a body is defined as the amount of heat energy required to raise the temperature of the (whole) body through 1 $^\circ$C or 1 K.

Heat capacity of the body $C'$ = Amount of heat/ Rise in temperature

$$C' = \Delta Q / \Delta T$$

**Units of heat capacity**

The SI unit of heat capacity is joules per degree Celsius ( J $^\circ C^{-1}$) or joules per kelvin ( J $K^{-1}$).

**Relation between heat capacity and specific heat**

Heat capacity = Mass × Specific heat

or Specific heat = Heat capacity/ Mass

So, specific heat of a body may be defined as its heat capacity per unit mass.

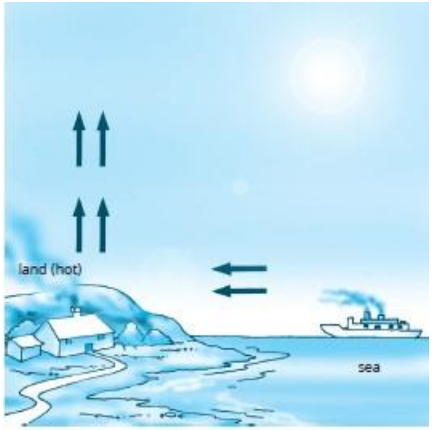
## Advantages of high specific heat capacity of water

1. Formation of land and sea breeze
2. Regulation of body temperature
3. Protection of crops from frost

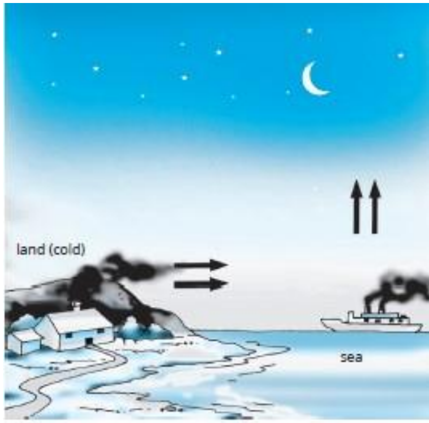
**General Applications**

1. As a coolant
2. For fomentation
3. Preventing freezing of bottled wines and juices
4. Lowering body temperature

**Note:** The differences between heat capacity and specific heat are given in Table 11.3.



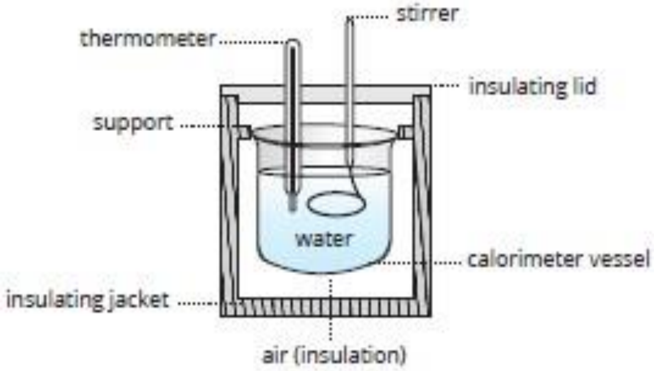

a. Sea breeze




b. Land breeze

## Calorimeter

Calorimetry is an experimental technique for the quantitative measurement of heat exchange. It is a cylindrical vessel, usually made of thin copper sheet. It is provided with a lid and a stirrer.




## Principle of calorimetry or (law of mixtures)

According to the principle of calorimetry (also called law of mixtures), **when two bodies at different temperatures are brought in contact, the quantity of heat lost by the hot body is equal to the heat gained by the cold body provided there is no change of state and no heat is lost to/gained from the surroundings**. This principle is based on the law of conservation of energy.

Heat lost by the hot body = Heat gained by the cold body

or Heat lost = Heat gained

or $m1 \times C1 \times (t1 - t) = m2 \times C2 \times (t - t2)$

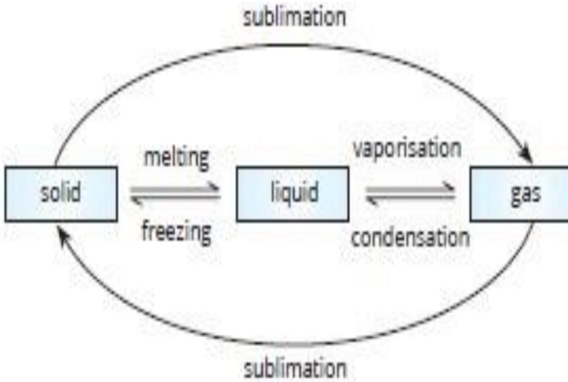
## Change of Phase or State

The change of a substance from one physical state to another at a constant temperature is called change of state. The change from solid to liquid state or phase is called **melting** and change from liquid to solid state or phase is called **freezing**.

The change from liquid to gas state or phase is called **vaporisation** and change from gas (or vapour) to liquid state or phase is called **condensation**. The change of state or phase of a solid directly into gaseous state (and vice versa) is called **sublimation**.

## Melting and freezing

The process in which a solid, on heating at a constant temperature, changes into liquid is called the **melting** or **fusion**.




The fixed temperature at which a solid gets converted into liquid is called the **melting point** of the substance. For example, ice melts at 0 ° C, so its melting point is 0 ° C.

The process in which a liquid substance on cooling at a constant temperature, changes into a solid is called **freezing** or **solidification**. For example, water crystallizes to ice at 0 ° C, so its freezing point is 0 ° C.

## Boiling and Condensation

The process in which a liquid, on heating at a constant temperature changes into gas (or vapour) phase is called **boiling** or **vaporisation**.

The fixed temperature at which a liquid gets converted into vapours is called the **boiling point** or **vaporisation temperature** of the substance. For example, water vaporises at 100 °C, so the boiling point of water is 100 °C.

The process in which vapours, on cooling at a constant temperature, change into liquid is called **condensation**.

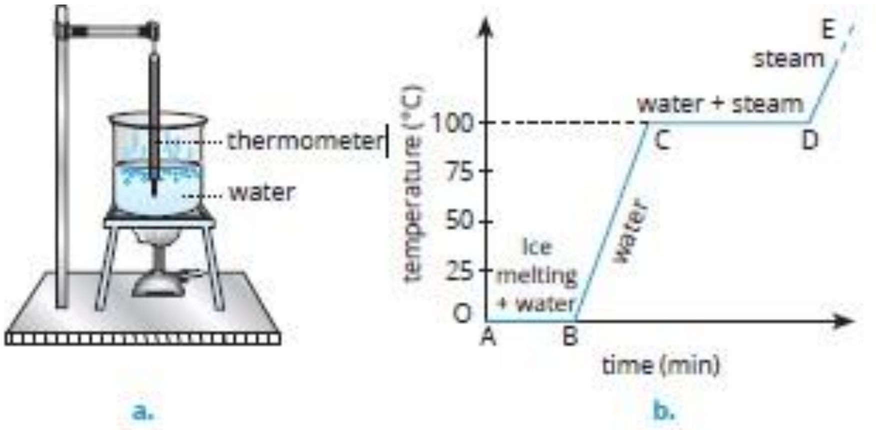
The fixed temperature at which vapours get converted into liquid is called the **condensation point** of the substance. For example, steam at 100 °C on cooling condenses into water, so the condensation point of steam is 100 °C.

## Sublimation

The change of state of a solid directly into its gaseous state, on heating, without going through the liquid state (and vice versa on cooling) is called **sublimation**.

## Heating Curve

The graph between the temperature of a substance being heated at a constant rate against time is called a temperature-time graph or heating curve for the substance.



The nature of the heating curve depends upon:

**1.** the range of temperature over which the substance is heated.

**2.** any change of state which might occur during heating.

## Latent Heat

The amount of heat needed to change the state of a given substance without any change in its temperature is called the **latent heat.**

**Specific latent heat:** The amount of heat required to change the state of unit mass of a substance without any change in the temperature is called the specific latent heat.

Depending upon the nature of the process, there are two kinds of latent heats:

**1.** The specific latent heat of fusion (or the latent heat of melting)

**2.** The specific latent heat of vaporisation.

## Specific latent heat of fusion (or the specific latent heat of melting)

The quantity of heat required to convert unit mass of the substance from solid state to liquid state at its melting point without any change of temperature is called the specific latent heat of fusion or the specific latent heat of melting.

Thus, if *Q* is the quantity of heat required to melt a mass *m* of a solid substance, then the latent heat of fusion for the substance is

$$L_{\text{fusion}} = \text{Quantity of heat absorbed during fusion (melting)} / \text{Mass of the substance melted}$$

## Natural consequences of latent heat of fusion of ice

Ice has a high specific latent heat of fusion (i.e. 336000 J kg–1). Thus, one kilogram of ice on melting absorbs 336000 joules of heat energy from the surroundings. It is due to this fact that

1. Snow on the mountains do not melt all at once.
2. It becomes bitterly cold as soon as the snow starts melting in cold countries.
3. The weather becomes very cold after the hailstorm because the heat is absorbed from the surrounding when ice melts.
4. Due to high specific latent heat of fusion of ice, icebergs are carried by ocean currents over very long distances.
5. Drinks are cooled by ice

## Specific latent heat of vaporisation

The quantity of heat required to convert unit mass of the substance from liquid state to vapour state at its boiling point without any change of temperature is called the specific latent heat of vaporisation.

Thus, if *Q* is the quantity of heat required to boil a mass *m* of a liquid substance, then the latent heat of vaporisation for the substance is

$L_{vap}$ = Quantity of heat absorbed during boiling (vaporisation) / Mass of the liquid substance vaporised

Or $L_{vap} = Q/m$

## Consequences of High Latent Heat of Vaporisation of Water

**Natural consequences**

1. Rainfall is regulated, hence the survival of life on earth
2. Plants are protected from wilting during summer

**General advantages**

2260000 joules of heat energy is released when 1 kg of steam condenses. This released energy is used for different purposes.

**1.** Running trains and machines.

**2.** At nuclear power plants and thermal power plants to generate electricity.

**3.** Heat water which can then be used in heating systems of buildings and in public services (heating purpose).

**4.** Steam press where it first softens the cloth and then straightens it at a low temperature as compared to the metallic press.

**Disadvantage of high latent heat of vaporisation of water**

The burns caused by steam are much more severe than those caused by boiling water though both of them are at the same temperature (100 $^\circ$C). Thus, 1 g of steam at 100 $^\circ$C contains 2260 J of heat energy more, in the form of latent heat, than water at 100 $^\circ$C. So, when steam comes in contact with our skin and condenses to produce water, it gives out heat energy equal to 2260 joules per gram.

# SUMMARY

1. **Temperature:** According to kinetic molecular theory, the temperature of a body is a measure of the average kinetic energy of that body.

2. **Calorimetry:** An experimental technique for the quantitative measurement of heat exchange is called calorimetry.

3. **Calorie:** One calorie of heat is the quantity of heat required to raise the temperature of one gram of pure water from 14.5 °C to 15.5 °C.

4. **Specific heat capacity of a substance:** It is defined as the amount of heat required to raise the temperature of unit mass of the substance through unit degree.

5. **Heat capacity of a body:** It is defined as the amount of heat required to raise the temperature of the whole body through 1 °C or 1 K.

6. **Principle of calorimetery:** When two bodies at different temperatures are brought in contact, the quantity of heat lost by the hot body is equal to the heat gained by the cold body provided there is no change of state or no heat is lost to/gained from the surroundings.

7. **Heating curve:** The graph between the temperature of a substance being heated at a constant rate against time is called the heating curve of a substance.

8. **Latent heat:** The amount of heat needed to change the state of a given substance without any change in temperature is called latent heat.

9. **Specific latent heat of fusion:** The quantity of heat required to convert one unit mass of the substance from solid state to the liquid state at its melting point without any change of temperature is called the specific latent heat of fusion.

10. **Specific latent heat and vaporisation:** The quantity of heat required to convert one unit mass of the substance from liquid state to the vapour state at its boiling point without any change of temperature is called specific latent heat of vaporisation.

11. **Specific latent heat of condensation:** The specific latent heat of vaporisation equals the specific latent heat of condensation.

RATNA SAGAR | PRIMUS | BYWORD | E-LIVE

# THANK YOU