1. Details of Module and its structure

Module Detail	
Subject Name	Physics
Course Name	Physics 02 (Physics Part-2 ,Class XI)
Module Name/Title	Unit 7, Module 15, Change of State Chapter 11, Thermal Properties of Matter
Module Id	keph_201104_eContent
Pre-requisites	Students should have knowledge of states of matter, thermal properties of matter, temperature, melting point , boiling point ,
Objectives	After going through this module, the learners will be able to: • Define latent heat and phase of substances • Know that pressure affects melting and boiling point • Interpret the phase diagram of water and understand the significance of triple point • Apply the principle of Calorimetry / law of mixtures to determine latent heat
Keywords	Change of state, triple point, law of mixtures, phase diagram, latent heat of fusion, latent heat of vaporization ,

2. Development Team

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UNIT 7:

PROPERTIES OF B ULK MATTER:

Chapter–9: Mechanical Properties of Solids:

Elastic behaviour, Stress-strain relationship, Hooke's law, Young's modulus, bulk modulus, shear, modulus of rigidity, Poisson's ratio, elastic energy.

Chapter–10: Mechanical Properties of Fluids:

Pressure due to a fluid column; Pascal's law and its applications(hydraulic lift and hydraulic brakes). Effect of gravity on fluid pressure. Viscosity, Stokes' law, terminal velocity, streamline and turbulent flow, critical velocity, Bernoulli's theorem and its applications. Surface energy and surface tension, angle of contact, excess of pressure across a curved surface, application of surface tension ideas to drops, bubbles and capillary rise

Chapter–11: Thermal Properties of Matter:

Heat, temperature, thermal expansion; thermal expansion of solids, liquids and gases, anomalous expansion of water; specific heat capacity; Cp, Cv - calorimetry; change of state - latent heat capacity. Heat transfer-conduction, convection and radiation, thermal conductivity, qualitative ideas of Blackbody radiation, Wien's displacement Law, Stefan's law, Greenhouse effect.

2. MODULE WISE DISTRIBUTION OF UNIT SYLLABUS 17 MODULES

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	• Study of a few selected properties of matter • Study of elastic behaviour of solids • Stationary fluid property: pressure and viscosity • Stationary liquid property: surface tension • Properties of Flowing fluids • Effect of heat on matter
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	• Temperature • Thermometers
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Module 15	• Change of state • To observe change of state and plot a cooling curve for molten wax. • Melting point, Regelation, Evaporation, boiling point, sublimation • Triple point of water • Latent heat of fusion • Latent heat of vaporization • Calorimetry and determination of specific latent heat capacity
Module 16	• Heat Transfer • Conduction, convection, radiation • Coefficient of thermal conductivity • Convection
Module 17	• Black body • Black body radiation • Wien's displacement law • Stefan's law • Newton's law of cooling, • To study the temperature, time relation for a hot body by

	plotting its cooling curve • **To study the factors affecting the rate of loss of heat of a liquid** • **Greenhouse effect**

MODULE 15

3. WORDS YOU MUST KNOW

Temperature: a measure of the warmth or coldness of an object or substance with reference to some standard/reference value.

Heat: Energy in transit; gets exchanged because of a difference in temperature.

Thermometer: a device to measure temperature.

Material: any homogeneous system, in any state: solid liquid or gas

Ice point: the freezing point of water of 0° Celsius or 273.15 kelvin at standard atmospheric pressure.

Freezing: the process of conversion of liquid to solid state. For water freezing means conversion to ice (its solid state)

Standard atmospheric pressure: The standard atmospheric pressure is the air pressure of 101325 pascal's (Pa) or 101.325 kilopascals (kPa) (1013.25 millibars), exerted by a 760 millimeter (29.92 inches) column of mercury at sea level at a temperature of 0 degrees Celsius.

Steam point: the normal boiling point of pure water that is used as one of the fixed points of the international temperature scale.

Boiling is the rapid vaporization of a liquid, which occurs when a liquid is heated to its **boiling** point, the temperature at which the vapour pressure of the liquid is equal to the pressure exerted on the liquid by the surrounding atmosphere

Evaporation is a type of vaporization that occurs on the surface of a liquid as it changes into the gaseous phase. The surrounding gas must not be saturated with the evaporating substance.

Ideal gas: a hypothetical gas whose molecules occupy negligible space and have no interactions with each other, and which consequently obeys the gas laws exactly.

Internal energy: The energy associated with the disordered, random motion of molecules is called Internal Energy. The total (internal) energy in a system includes potential and kinetic *energy*.

Thermal energy: is the internal **energy** of an object due to the kinetic **energy** of its atoms and/or molecules. The atoms and/or molecules of a hotter object have greater kinetic **energy** than those of a colder object. Heat is the flow of thermal energy.

Triple point: A temperature at normal pressure where matter can exist in three states of matter (solid, liquid and gas) at triple point of water we will have ice water and water vapor. they would all be at the same temperature

Absolute temperature: Absolute temperature, also called thermodynamic temperature, is the temperature of an object on a scale where 0 is taken as absolute zero.

Thermal capacity: Thermal capacity, also referred to as heat capacity, is the amount of heat required to change the temperature of an object by a certain degree. This means that it varies per amount of the substance.

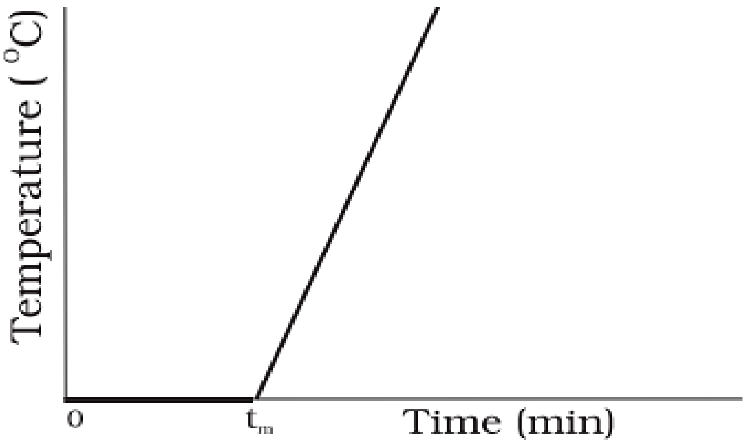
4. INTRODUCTION

Matter normally exists in three states: solid, liquid, and gas. A transition from one of these states to another is called a change of state. Two common changes of states are solid to liquid and liquid to gas (and vice versa).

These changes can occur when the exchange of heat takes place between the substance and its surroundings.

To study the change of state on heating or cooling, let us perform the following activity. Take some cubes of ice in a glass. You will need a thermometer (not the clinical one used for measuring Body temperature)

Note the temperature of ice (0 °C) allow it to stand on a table top. Note the room temperature. Note the temperature after every minute. Continuously stir the mixture of water and ice. If you were to plot a graph of beaker content temperature and time it would look as shown

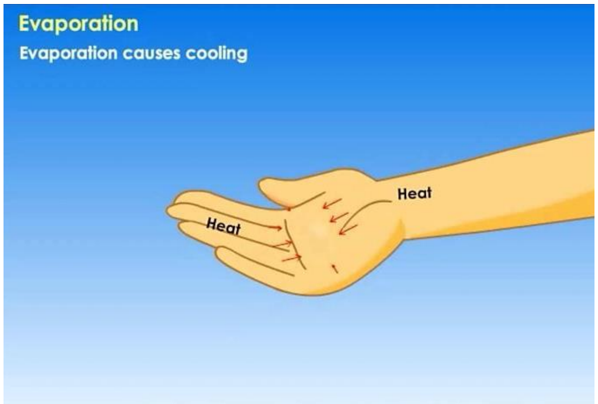


You will observe **no change in the temperature so long as there is ice in the beaker.**

In the above process, the temperature of the system does not change even though heat is melting the ice. The heat absorbed is being utilized in changing the state from solid (ice) to liquid (water).

Similar situation arises when liquid changes to vapour state.

When we wash our hands and let them dry on their own, means not wipe them dry using a towel. We feel our hands getting a cool feeling. This is because, water absorbs heat from the body and converts it to water vapor. **Why do we use earthen pots to cool water?**



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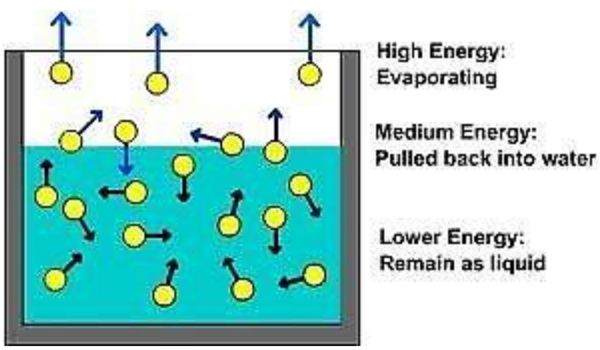
Interesting to observe is the temperature of water in a container, is less than the room temperature, because of evaporation**. This can be explained by saying the molecules of water do not possess the same energy.**



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The molecules with higher energy can escape and the net molecular energy of remaining water decreases.

The two important temperatures for pure water at normal atmospheric pressure are

- **Freezing point of water or melting point of ice or lower fixed point for a thermometer = 0^0 C or 273 K**
- **Boiling point of water or temperature of condensation or upper fixed point of a thermometer = 100^0 C or 373 K**

5. CHANGE OF STATE

Matter exists in three states –solid liquid and gas. The change from one to the other is called change of state.

Do you think the change of state must depend upon some factors? What would these factors be?

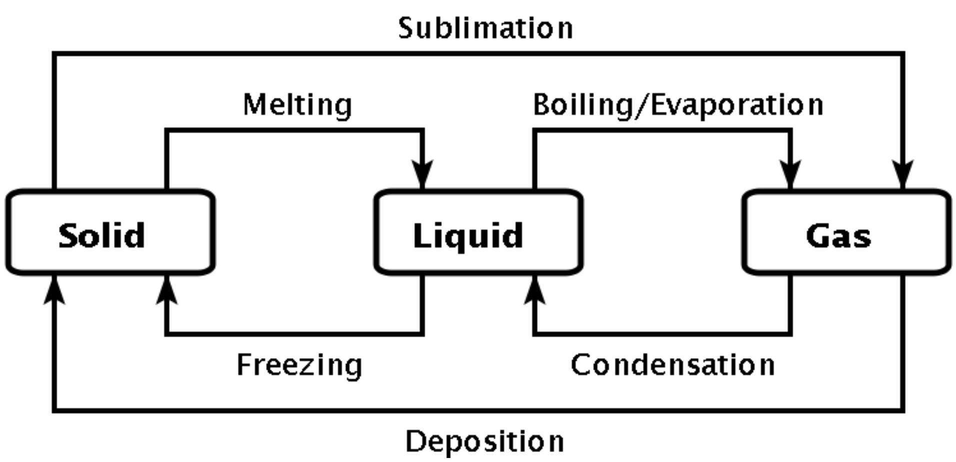
- **Substance/material / nature of matter**
- **Purity of substance**
- **Temperature of substance/material**
- **Temperature of surrounding of the substance/material**
- **Pressure on the substance/material**

Let us examine each of these factors.

When we look around us say in a kitchen, there are lots of articles in solid state –utensils, you may have some in liquid state –water oil, vinegar and some in gaseous state water vapor, fumes, air.

At the same temperature articles kept outside in the kitchen can be in any state of matter depending upon their composition (material).

We had discussed how some ice cubes kept in a glass melted, the cubes would have remained in solid (ice) state inside the freezer compartment, had they not been brought out. What about the water used for making tea, it boils and you are able to see the water vapor rising from the boiling pot? To convince ourselves that it is water vapor, you may hold a steel glass with ice cubes near the steam, the condensation of water vapor in to water will show the change of state from vapor to liquid.



https://commons.wikimedia.org/wiki/File:Phase_changes.svg

The diagram shows the names associated with specific change of states

The change of state from solid to liquid is called **melting** and from liquid to solid is called **fusion or freezing.** It is observed that the temperature remains constant until the entire amount of the solid substance melts. That is, both the solid and liquid states of the substance coexist in thermal equilibrium during the change of states from solid to liquid.

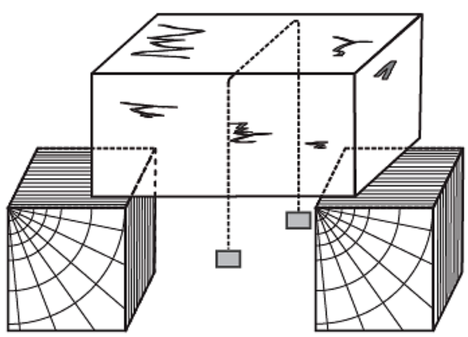
The temperature at which the solid and the liquid states of the substance in thermal equilibrium with each other is called melting point.

It is characteristic of the substance.

It also depends on pressure.

The melting point of a substance at standard atmospheric pressure is called its **normal melting point.**

We can do the following activity to understand the process of melting of ice. Take a slab of ice. Take a metallic wire and fix two blocks, say 5 kg each, at its ends. Put the wire over the slab as shown in fig.



You will observe that the wire passes through the ice slab.

This happens due to the fact that just below the wire, ice melts at lower temperature due to increase in pressure. As the wire passes through, water above the wire freezes again. Thus the wire passes through the slab and the slab does not split. This phenomenon of refreezing is called regelation.

THINK ABOUT THIS

- Skating is possible on ice due to the formation of water below the skates. Water is formed due to the pressure exerted by the skater and it acts as a lubricant.

https://www.maxpixel.net/static/photo/1x/Ice-The-Blade-Skates-Polar-Area-The-Ice-Rink-2827707.jpg

https://upload.wikimedia.org/wikipedia/en/a/a5/Tubeice.jpg

- If we take two cubes of ice and press them together they stick to each other.

So we can say

The change of state involves temperatures

Melting- Conversion of solid into liquid state at constant temperature (under given conditions) is known melting.

- **Evaporation:** molecules in a liquid do not have the same kinetic energy. The ones with higher kinetic energy escape to the space above the liquid, these may even fall back in case their energy drops or escape in the atmosphere. So evaporation happens at all temperatures of the liquid state. Evaporation of water is easy to observe, the water in a plate disappears after some time. Our observations with drying washed clothes show that clothes dry faster in the sun and on a windy day. in rainy season clothes take longer to dry

Evaporation- **Conversion of liquid into vapours at all temperatures is called evaporation.**
It is a surface phenomenon.
Greater the temperature, faster is the evaporation. Smaller the boiling point of liquid, more rapid is the evaporation.
Smaller the humidity more is the evaporation.
Evaporation increases on decreasing pressure; that is why evaporation is faster in vacuum.

- **Boiling-** Evaporation over the whole mass of the liquid, is called boiling. Under given conditions, boiling takes place at a constant temperature known as boiling point. **A liquid boils when the vapour pressure on its surface is equal to atmospheric pressure. Boiling point reduces on decreasing pressure.**

https://upload.wikimedia.org/wikipedia/commons/2/28/Fissler_Dampfkochtopf_Vitavit.jpg

Why does a pressure cooker cook the food faster?
We use a pressure cooker in the kitchen. The boiling point of water increases due to the additional weight placed on the opening in the lid of the cooker. The water vapor collects on top of the boiling water in the food being cooked. The temperature of this boiling water is therefore higher than normal and so the food cooks faster.

Heat of evaporation- **Heat required to change unit mass of a liquid into vapour, at a given temperature, is called the heat of evaporation at that temperature.**

- **Sublimation-** Direct conversion of solid into vapour state is called sublimation.

- **Heat of sublimation-** Heat required to change unit mass of solid directly into vapours, at a given temperature, is called the heat of sublimation at that temperature.

Camphor and ammonium chloride sublimates on heating in normal conditions.

A block of ice sublimates into vapours on the surface of moon because of the very-very low pressure on its surface.

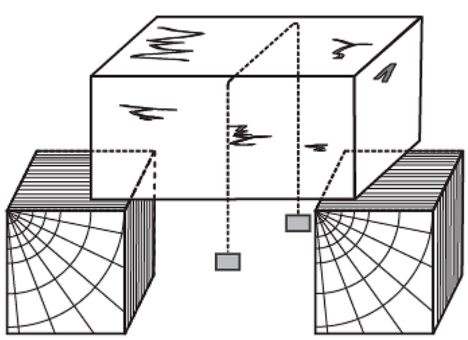
Dry ice (solid CO_2) sublimes, so also iodine. During the sublimation process both the solid and vapour states of a substance coexist in thermal equilibrium.

- **Condensation-** The process of conversion, from gaseous (or vapour) state to liquid state, is known as condensation.

- **Deposition**
- **:** Direct conversion of vapours into solid is called hoar frost. This process may be viewed as just the reverse of the process of sublimation.

Formation of snow, through freezing of clouds, may be viewed as an example of deposition also called hoar frost.

- **Regelation-** Regelation is the melting of ice caused by pressure and its resolidification when the pressure is removed.
Ice contracts when it melts.
When pressure is applied, to deliberately promote shrinkage, that also helps to assist the process of melting.
In other words, melting of cold ice is ordinarily effected by raising the temperature.
However, **if pressure is present to help with the shrinkage, melting can occur even without raising the temperature**.



Melting takes place under the wire because pressure lowers the melting temperature. Refreezing (regelation) occurs above the wire when the pressure above the water, just formed through melting, becomes normal pressure again. But the ice water should be at freezing point.

Increase of pressure lowers the melting (or freezing) point of water. For most of the other substances, which normally, if expands on melting, the melting point is raised by increase of pressure.

ICE TO WATER VAPOUR

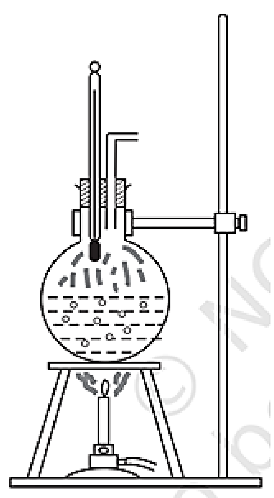
Take some ice in a round bottom flask as shown, heat it. After the whole of ice gets converted into water and as we continue further heating, we shall see that temperature begins to rise. The temperature keeps on rising till it reaches nearly100 °C when it again becomes steady. The heat supplied is now being utilized to change water from liquid state to vapour or gaseous state. During vaporisation, it is observed that the temperature remains constant until the entire amount of the liquid is converted into vapour. That is, both the liquid and vapour states of the substance coexist in thermal equilibrium, during the change of state from liquid to vapour.

So temperature of ice and ice water remained at 0^0C till all the ice converted to water .and the temperature of water and steam remained the same as boiling point of water =100^0C

Let us do the following activity to understand the process of boiling of water.

Take a round-bottom flask, more than half filled with water. Keep it over a burner and fix a thermometer and steam outlet through the cork of the flask

As water gets heated in the flask, note first that the air, which was dissolved in the water, will come out as small bubbles. Later, bubbles of steam will form at the bottom but as they rise to the cooler water near the top, they condense and disappear. Finally, as the temperature of the entire mass of the water reaches 100 °C, bubbles of steam reach the surface and boiling is said to occur. The steam in the flask may not be visible but as it comes out of the flask, it condenses as tiny droplets of water, giving a foggy appearance. If now the steam outlet is closed for a few seconds to increase the pressure in the flask, you will notice that boiling stops. More heat would be required to raise the temperature (depending on the increase in pressure) before boiling begins again. Thus boiling point increases with increase in pressure (principle of pressure cooker).



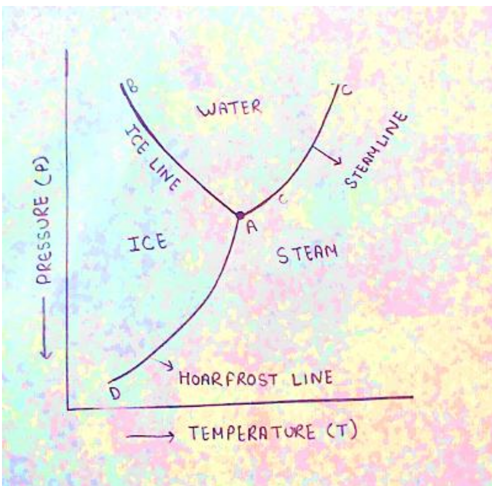
Arrangement to study the Boiling process.

Let us now remove the burner. Allow water to cool to about 80 °C. Remove the thermometer and steam outlet. Close the flask with the air tight cork. Keep the flask turned upside down on the stand. Pour ice-cold water on the flask. Water vapours in the flask condense reducing the pressure on the water surface inside the flask. Water begins to boil again, now at a lower temperature. Thus boiling point decreases with decrease in pressure. **This explains why cooking is difficult on hills**. At high altitudes, atmospheric pressure is lower, reducing the boiling point of water as compared to that at sea level. On the other hand, boiling point is increased inside a pressure cooker by increasing the pressure. Hence cooking is faster.

The boiling point of a substance at standard atmospheric pressure is called its normal boiling point.

However, all substances do not pass through the three states: solid-liquid-gas. There are certain substances which normally pass from the solid to the vapour state directly and vice versa.

6. PHASE OF A SUBSTANCE-



The phase of a substance is defined as its form which is homogeneous, physically distinct and mechanically separate from the other forms of that substance.

Phase diagram-

- A phase diagram is a graph in which pressure (P) is represented along the y-axis and temperature (T) is represented along the x-axis.
- **Characteristics of Phase diagram-**

(i) Different phases of a substances can be shown on a given phase diagram.
(ii) A region on the phase diagram represents a single phase of the substance; a curve represents equilibrium between two phases and a common point represents equilibrium between three phases.
(iii) A phase diagram helps to determine the conditions under which the different phases are in equilibrium.
(iv) A phase diagram is useful for finding a convenient way in which a given desired change of phase can be produced.

PHASE DIAGRAM FOR WATER-

The phase diagram for water consists of three curves AB, AC and AD meeting each other at the point A. These curves divide the phase diagram into three regions.

Region, to the left of the curve AB and above the curve AD, represents the solid phase of water (ice).

The region, to the right of the curve AB and above the curve AC, represents the liquid phase of water.

The region, below the curves AC and AD, represents the gaseous phase of water (i.e. water vapour).

A curve, on the phase diagram, represents the boundary between two phases of the substance.

Along any curve, two of the phases can coexist in equilibrium-

- **Along curve AB, ice and water can remain in equilibrium. This curve is called fusion curve or ice line. This curve shows that melting point of ice decreases with increase in pressure.**
- **Along the curve AC, water and water vapour can remain in equilibrium. The curve is called vaporisation curve or steam line. The curve shows that the boiling point of water increases with increase in pressure**.
- **Along the curve AD, ice and water vapour can remain in equilibrium. This curve is called sublimation curve or hoar frost line.**

TRIPLE POINT OF WATER-

The three curves in the phase diagram of water, meet at a single point A, which is called the triple point of water. **The triple point of water corresponds to the co-existence of all the three phases of water: ice, water and water vapour in equilibrium**.

The pressure, corresponding to triple point of water is 6.03×10^{-3} atmosphere or 4.58 mm of Hg and the temperature corresponding to it is 273.16K.

Significance of triple point of water

The **kelvin** is defined as the 1/273.16 fraction of the temperature of the **triple point of water** (exactly 0.01 °C).

In other words, it is defined such that the **triple point of water** is exactly 273.16 K.

The definition implies that absolute zero (0 K) is equivalent to −273.15 °C

Effect of change in pressure on M.P. and B.P. for water

- On increasing the pressure melting point decreases and boiling pint increases
- On decreasing the pressure melting point increases and boiling pint decreases

THINK ABOUT THESE

- **A bottle is filled with water at 30°C. On opening it on the moon, this water (at 30°C) will start boiling and get vaporized.**
- **More energy is wasted in cooking food in the hills**
- **Water is added to cook food in the pressure cookers**

7. LATENT HEAT

We have learnt that certain amount of heat energy is transferred between a substance and its surroundings when it undergoes a change of state.

The amount of heat per unit mass transferred during change of state of the substance is called latent heat of the substance for the process.

For example, if heat is added to a given quantity of ice at –10 °C, the temperature of ice increases until it reaches its melting point (0 °C). At this temperature, the addition of more heat does not increase the temperature but causes the ice to melt, or changes its state. Once the entire ice melts, adding more heat will cause the temperature of the water to rise.

A similar situation occurs during liquid gas change of state at the boiling point. Adding more heat to boiling water causes vaporisation, without increase in temperature.

The heat required during a change of state depends upon the heat of transformation and the mass of the substance undergoing a change of state.

Thus,

If **mass m** of a substance undergoes a change from one state to the other, then the quantity of heat required is given by

$Q = m L$ or $L = Q/m$

Where **L is known as latent heat** and is a **characteristic of the substance**.

Its **SI unit is J kg^{-1}.**

The value of L also **depends on the pressure.**

Its value is usually quoted at standard atmospheric pressure.

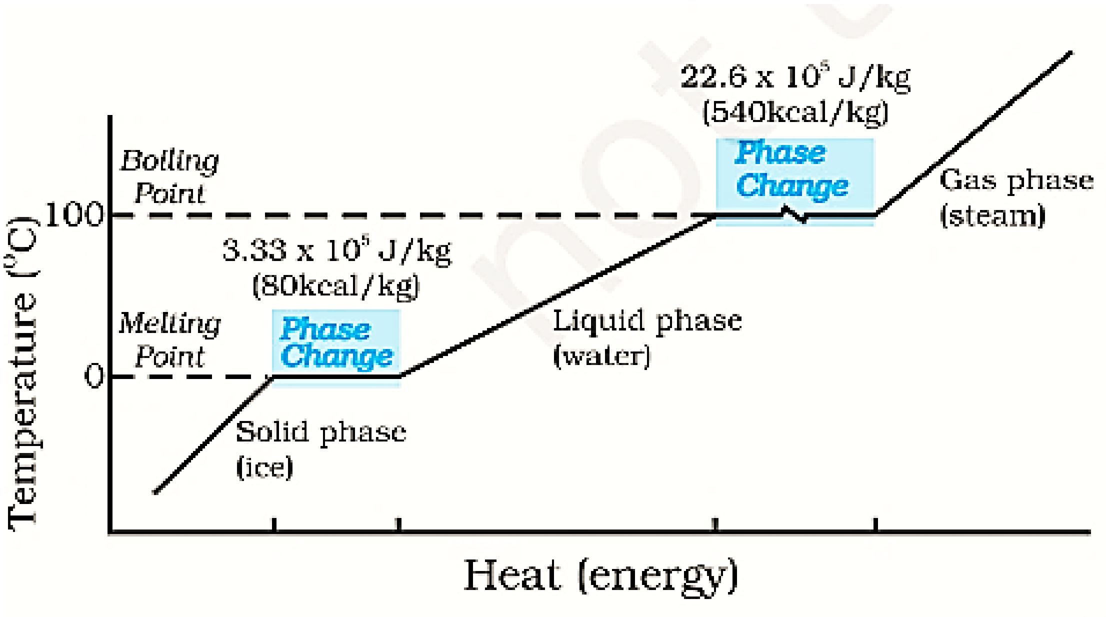
The latent heat for a solid -liquid state change is called the latent heat of fusion (L_f),

and

That for a liquid-gas state change is called the latent heat of vaporisation (Lv).

These are often referred to as **the heat of fusion and the heat of vaporisation**.

A plot of temperature versus heat energy for a quantity of water is shown in the graph



Temperature versus heat for water at 1 atm pressure (not to scale).

The latent heats of some substances, their freezing and boiling points, are given in Table

Temperatures of the change of state and latent heats for various substances at 1 atm pressure

Substance	Melting Point (°C)	L_f (10^5J kg^{-1})	Boiling Point (°C)	L_v (10^5J kg^{-1})
Ethyl alcohol	–114	1.0	78	8.5
Gold	1063	0.645	2660	15.8
Lead	328	0.25	1744	8.67
Mercury	–39	0.12	357	2.7
Nitrogen	–210	0.26	–196	2.0
Oxygen	–219	0.14	–183	2.1
Water	0	3.33	100	22.6

Note

- That when heat is added (or removed) during a change of state, the temperature remains constant.
- The temperature does not rise as all the energy is used to make or break the intermolecular bonds, since the bond energies are fixed the latent heat values are constant for a substance.

- That the slopes of the phase lines are not all the same, which indicates that specific heats of the various states are not equal.
- For water,

  Latent heat of fusion $L_f = 3.33 \times 10^5$ J kg^{-1}

  Latent heat of vaporization $L_v = 22.6 \times 10^5$ J kg^{-1}

- That is 3.33×10^5 J of heat are needed to melt 1 kg of ice at 0 °C, and 22.6×10^5 J of heat are needed to convert 1 kg of water to steam at 100 °C.
- So, steam at 100 °C carries 22.6×10^5 J kg^{-1} more heat than water at 100 °C.
- This is **why burns from steam are usually more serious than those from boiling water.**

EXAMPLE

A copper block of mass 2.5 kg is heated in a furnace to a temperature of 500 °C and then placed on a large ice block.

What is the maximum amount of ice that can melt?

(Specific heat of copper = 0.39 $Jg^{-1}K^{-1}$; heat of fusion of water = 335 J g^{-1}).

SOLUTION

Given: mass of the copper block, $M_1 = 2.5\ kg$

Specific heat of copper = 0.39 J$g^{-1}K^{-1} = 0.39 \times 10^3\ Jkg^{-1}K^{-1}$

Temperature of the furnace, $\theta = 500$ °C

Therefore, heat absorbed by the copper block,

$$Q = M_1\, S\, \theta = 2.5 \times 0.39 \times 10^3 \times 500$$

Latent heat of ice, L = 335 J $g^{-1} = 335 \times 10^3 Jkg^{-1}$

Suppose that mass $M_2 (in\ kg)$ of the ice melts, when the copper block is placed on it. Then

$$Q = M_2 L = M_2 \times 335 \times 10^3$$

After comparing both equations, we get

$$M_2 \times 335 \times 10^3 = 2.5 \times 0.39 \times 10^3 \times 500$$

$$M_2 = \frac{2.5 \times 0.39 \times 10^3 \times 500}{335 \times 10^3} = 1.455 \text{ kg}$$

EXAMPLE

A child running a temperature of 101°F is given an antipyrin (i.e. a medicine that lowers fever) which causes an increase in the rate of evaporation of sweat from his body. If the fever is brought down to 98 °F in 20 min, what is the average rate of extra evaporation caused, by the drug?

Assume the evaporation mechanism is the only way by which heat is lost.

The mass of the child is 30 kg. The specific heat of human body is approximately the same as that of water, and latent heat of evaporation of water at that temperature is about 580 cal g^{-1}.

SOLUTION

Mass of the child, M = 30 kg

$$\Delta T = 101 - 98 = 3°\text{F} = \frac{3 \times 100}{180} = \frac{5}{3}°\text{C}$$

Specific heat of the human body (specific heat of water),

S = 4.2× $10^3\ J\ kg^{-1}°\text{C}^{-1}$

Therefore, heat lost by child due to evaporation in the form of sweat,

Q = M c ΔT

$= 30 \times 4.2 \times 10^3 \times \frac{5}{3} = 2.1 \times 10^5 J$

If M ´gram of sweat evaporates from the body of the child in 20 min, then

Q = M ´L

Here, L = 580 cal g^{-1} = 580 × 4.2 × $10^3\ J\ kg^{-1}$

$\therefore M' = \frac{Q}{L} = \frac{2.1 \times 10^5}{580 \times 4.2 \times 10^3} = 0.0862\ kg$

Time taken by sweat to evaporate = 20 min

Therefore, rate of evaporation of sweat $= \frac{0.0862}{20} = 0.00431\ kg\ min^{-1}$

$$= \mathbf{4.31\ g\ min^{-1}}$$

8. TO OBSERVE THE CHANGE OF STATE AND PLOT A COOLING CURVE FOR MOLTEN WAX.

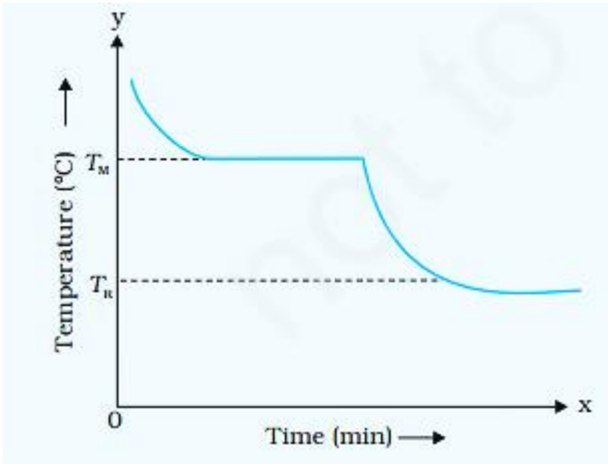
APPARATUS AND MATERIAL REQUIRED

- A 500 mL beaker,
- tripod stand, wire gauge, clamp stand,
- Hard glass boiling tube,
- Celsius thermometer of least count 0.5 °C,
- A stop-watch/ stop-clock,
- Burner,
- Parraffin wax,
- Cork with a hole that fits the boiling tube and can hold a thermometer vertically.

PRINCIPLE

. If we continue to heat the solid, it changes its state. The process of conversion of solid to a liquid state is called melting. Under given conditions, the temperature at which the change takes place is called melting point. Melting does not take place instantaneously throughout the bulk of a solid; the temperature of the solid-liquid combine remains constant till the whole solid changes into liquid. The time for melting depends upon the nature and mass of solid. A liquid, when cooled,(under given conditions) freezes to solid state at the same temperature as its melting point. In this case also the temperature of liquid-solid remains constant till all the liquid solidifies.

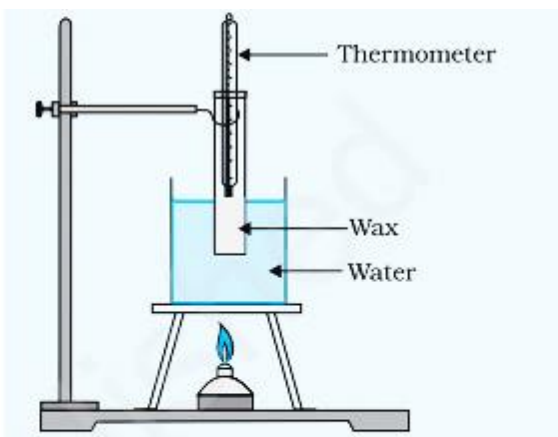
Paraffin wax is widely used in daily life. We can determine the melting point of wax by plotting its cooling curve. The temperature of molten wax is recorded at equal intervals of time. Initially, the temperature of molten wax falls with time; becomes constant at T_M, the melting point, where it starts getting solidified. After the whole of the molten wax gets solidified, the temperature of the solid wax again starts falling till it becomes equal to T_R, the room temperature.



Cooling curve for paraffin wax

PROCEDURE

1. Note the least count and range of the thermometer.
2. Note the least count of the stop-clock.
3. Record the room temperature.
4. Set up the tripod, burner, heating arrangement as shown in Fig



Experimental set up

5. Adjust the boiling tube and the thermometer such that the graduation marks can be easily read by you.
6. Heat the water and observe the state of wax. Continue to heat till all the wax melts. Note the (approximate) melting point. Say upto 85^0C
7. Turn off the burner, and carefully raise the clamp to remove the boiling tube from the water bath.
9. Record readings of temperature after every 1 minute.
10. Plot a graph of temperature of wax versus time,- (temperature on y – axis).

11. From the graph
(i) determine the melting point of wax.
(ii) mark the time interval for which the wax is in liquid state/solid state.

OBSERVATIONS

Least count of thermometer = ... °C
Thermometer range ... °C to ... °C
Room temperature = ... °C
Least count of stop clock = ... s
Change in temperature of molten wax with time

S. No.	time s	temperature C
1		
2		
3		
4		

RESULT

The cooling curve of molten wax is shown in the graph. From the graph
(i) The melting point of wax is ... °C and
(ii) The wax remains in liquid-solid state for …. (s)

PRECAUTIONS

- The boiling tube with wax should never be heated directly on a flame.
- The stop clock should be placed on the right hand side of the apparatus where it may be easy to see it.
- Wax should not be heated more than 20°C above its melting point

SOURCES OF ERROR

Simultaneous recording of temperature and time may give rise to some errors.

THINK ABOUT THESE

- **Why should we never heat the wax directly over a flame?**
- **Why is water bath used to melt the wax and heat it further?**
- **What is the maximum temperature to which molten wax can be heated in a water bath?**
- **Would this method be suitable to determine the melting point of plastics? Give reason for your answer.**
- **Will the shape of the curve, for cooling of hot water, be different than that for wax?**

9. LAW OF MIXTURES / PRINCIPLES OF CALORIMETRY

When two bodies (one being solid and other liquid or both being liquid) at different temperatures are mixed, heat will be transferred from body at higher temperature to a body at lower temperature till both acquire the same temperature. The body at higher temperature releases heat while the body at lower temperature absorbs it, we have

Heat lost = Heat gained

(Principle of Calorimetry)

Principle of Calorimetry represents the law of conservation of heat energy. It, of course, assumes that there is no gain or loss of heat between the substances and their surroundings.

We can understand this method for determination of latent heat in the laboratory by these examples

EXAMPLE

When 0.15 kg of ice of 0 °C mixed with 0.30 kg of water at 50 °C in a container, the resulting temperature is 6.7 °C. Calculate the heat of fusion of ice.

(s_{water} = 4186 $J\ kg^{-1}K^{-1}$)

SOLUTION

Heat lost by water = $ms_w\left(\theta_f - \theta_i\right)_w$

= (0.30 kg) (4186 J $kg^{-1}K^{-1}$) (50.0 °C – 6.7 °C)

= 54376.14 J

Heat required to melt ice = m_2L_f = (0.15 kg) L_f

Heat required to raise temperature of ice water to final temperature =$m_I s_w\left(\theta_f - \theta_i\right)_I$

= (0.15 kg) (4186 J$kg^{-1}K^{-1}$) (6.7 °C – 0 °C)

= 4206.93 J

Heat lost = heat gained

54376.14 J = (0.15 kg) L_f + 4206.93 J

$\boldsymbol{L_f}$ **= 3.34×$\mathbf{10^5}$ J $\boldsymbol{kg^{-1}}$**

EXAMPLE

Calculate the heat required to convert 3 kg of ice at –12 °C kept in a calorimeter to steam at 100 °C at atmospheric pressure. Given specific heat capacity of ice = 2100 J $\boldsymbol{kg^{-1}K^{-1}}$, specific heat capacity of water = 4186 J $\boldsymbol{kg^{-1}K^{-1}}$,latent heat of fusion of ice = 3.35 × $\mathbf{10^5}$J $\boldsymbol{kg^{-1}}$ and latent heat of steam = 2.256 ×$\mathbf{10^6}$ J $\boldsymbol{kg^{-1}}$.

SOLUTION

We are given

Mass of the ice, *m* = 3 kg

Specific heat capacity of ice, $\boldsymbol{s_{Ice}}$= 2100 J $kg^{-1}K^{-1}$

Specific heat capacity of water, $\boldsymbol{s_{water}}$= 4186 J $kg^{-1}K^{-1}$

Latent heat of fusion of ice, $L_{f\ ice}$ = 3.35 × 10^5 J kg^{-1}

Latent heat of steam, L_{steam} = 2.256 × 10^6J kg^{-1}

Now, $\boldsymbol{Q}$ **= heat required to convert 3 kg of ice at –12 °C to steam at 100 °C,**

$\boldsymbol{Q_1}$ **= heat required to convert ice at –12 °C to ice at 0 °C.**

= *m* $\boldsymbol{s_{Ice}\Delta T_1}$

= (3 kg) (2100 J $kg^{-1}K^{-1}$) [0–(–12)]°C

= 75600 J

$\boldsymbol{Q_2}$ **= heat required to melt ice at 0 °C to water at 0 °C**

= m $L_{f\ ice}$

= (3 kg) (3.35 × $10^5 Jkg^{-1}$)

= 1005000 J

$\boldsymbol{Q_3}$ **= heat required to convert water at 0 °C to water at 100 °C.**

$= m s_w \Delta T_2$

= (3kg) (4186J$kg^{-1}K^{-1}$)(100 °C)

= 1255800 J

$\boldsymbol{Q_4}$ **= heat required to convert water at 100 °C to steam at 100 °C.**

$= mL_{steam}$

= (3 kg) (2.256×10^6 J kg^{-1})

= 6768000 J

So, $Q = Q_1 + Q_2 + Q_3 + Q_4$

= 75600J + 1005000 J + 1255800 J + 6768000 J

= 9.1×$\mathbf{10^6}$J

10 SUMMARY

In this module we have learnt

- Matter exists in three states solid liquid and gas
- The state can be changed by addition or removal of heat from a substance
- Pressure effects the change in state
- During the change of state, the temperature of the substance remains constant. Cooling curves can be drawn to substantiate the statement.
- latent heat of fusion is the amount of heat required by a unit mass of substance to change its state from liquid to solid at its freezing point
- latent heat of melting is equal to latent heat of fusion and the unit is J kg^{-}
- latent heat of vaporization corresponds to amount of heat required by a unit mass of substance to change its state from liquid to vapor at its boiling point at normal atmospheric pressure