1 HEAT

What we have already learnt

- Heat is measured in the unit joule. Calorie is also used as a unit. One calorie = 4.2 joule
- Celsius, Fahrenheit and kelvin are the units used to measure temperature.
- We know the properties of solids, liquids and gases based on kinetic theory
- Heat capacity of an object is the quantity of heat required to raise its temperature by 1°C.
- The boiling point of water is 100°C at standard atmospheric pressure.
- Atmospheric pressure is the weight of air column experienced by unit surface area of the earth.

Heat energy is highly related to our daily life. We have discussed about heat and temperature in lower classes. We also have some knowledge about kinetic theory of heat. But we have to gain some basic knowledge about the characteristics of heat and the technology using this. The main aim of this chapter is to make clear the scientific ideas involved in calculating the amount of heat energy supplied to an object when heated, its change of state and to discuss how these ideas are applied in our daily life.

1.01 Specific heat capacity

Is the increase in temperature the same when the same amount of heat is supplied to different substances? Let us do a simple experiment. Take four vessels of equal size. Pour 200g water, 400g water, 200g coconut oil and 400 g coconut oil in each vessel. Heat the four vessels using the same source. Note on the table 1.1 the time taken to raise the temperature of each from 35°C to 55°C.

We understand from the table that the quantity of heat supplied to raise the temperature of different substances by the same amount is different for different substances. Similarly, don't you see that for the same substance , if mass is different the quantity of heat supplied to raise the temperature for a definite amount is also different.

The following factors influence the quantity of heat supplied to an object when heated.

- Difference in temperature
- Mass
- Nature of substances

You have learnt that heat capacity is the quantity of heat required to raise the temperature of an object by 1°C.

From the above experiment you have seen that heat required to raise the temperature of 200g water by 20°C and that of coconut oil by the same temperature are different. That is the quantity of heat depends on the nature of the substances.

Therefore the quantity of heat needed to raise the temperature of 1kg of water by 1°C and that for 1 kg of coconut oil are different.

The quantity of heat required to raise the temperature of 1kg of substance by 1°C or 1K is its specific heat capacity.

Substance	**Time to reach 35^0C**	**Time to reach 55^0C**	**Time taken for the temperature to rise from 35^0C-55^0C (20^0C)**
200g of water			
200g of coconut oil			
400g of water			
400g of coconut oil			

Table 1.1

J/kgK is its unit. J/kg°Cis also used.

Specific heat capacities of certain substances are given below.

Substance	Specific heat capacity (J/kgK)
Aluminium	900
Iron	460
Copper	385
Water	4200
Glass	677
Ice	2130
Silver	234
Mercury	138
Coconut oil	2100

Table 1.2

From this we can see that water has the highest specific heat capacity. Discuss and note down how this is beneficial in our daily life.

- About 80% of the body of the plants and animals is comprised of water. It is because of the high specific heat capacity of water that small changes in the atmospheric temperature don't affect their body quickly.
- In cold countries agricultural fields are watered during the evenings. When atmosphere cools water also gets cooled. Then more heat is liberated. Therefore the temperature of the field does not decrease. Owing to this the seeds are protected.
- Water is used in the radiators of vehicles. Even though water receives a lot of heat from the engine, due to its high specific heat capacity the temperature of water does not change much.
- Specific heat capacity of water is five times that of sand. So during day time land gets heated fast and the sea gets heated slowly. But during night land cools fast and sea slowly. As a result of this sea breeze occurs during day time and land breeze during night.

1.02 Quantity of heat

We have seen that the specific heat capacity of a substance (c) is the amount of heat needed to raise the temperature of 1kg of the substance by 1°C.

Therefore heat required to raise the temperature of a substance of mass m kg by 1°C will be $m \times c \times 1$. From this we can understand that the quantity of heat required to raise the temperature of a substance of mass m kg by θ^0C is $Q = m \times c \times \theta$.

Using the above equation, fill up the table 1.3 given below.

Substance	Mass (m) kg	Specific heat capacity (c) J/kg°C	Increase in temperature θ°C	Heat taken by the substance Q= mcθ (joule)
Copper	1	385	10	3850
Iron	1	460	20	.....
Water	2	4200	.....	42000
Lead	1	.....	10	1290

Table 1.3

- Calculate the heat required to raise the temperature of 2kg of iron from 30°C to 60°C (the specific heat capacity of iron = 460J/kg°C)
- Calculate the heat required to raise the temperature of 5g of mercury from 20°C to 200°C (Specific heat capacity of mercury = 138J/kg°C)

1.03 Principle of method of mixtures

Take 200g cold water in one beaker and 200g hot water in another. Using a thermometer find out the temperature of water in each and write it in the table 1.4. Pour the cold water into the hot water, stir it and find out the resultant temperature and write it in the table.

When two objects of different temperatures are in contact heat flows from the body of higher temperature to that of lower temperature till the temperatures of both become equal. Heat lost by the hot body is equal to the heat gained by the cold body. This is the principle of method of mixtures.

1.04 Change of state

You might have seen water becoming steam and wax, ice etc melting when heated. You have also seen that water can exist in the solid state as ice and as steam in the gaseous state.

Specific heat capacity of water = 4200J/kg^{0}C

Water	Mass (kg)	Initial temperature	Resultant temperature of the mixture	Difference in temperature	Heat gained	Heat lost
Cold						
Hot						

Table 1.4

Analyse the table 1.4 and examine the relation between the quantity of heat gained by the cold water and the heat lost by hot water. What is your inference?

We can change the state of an object either by supplying heat to or by removing heat from it.

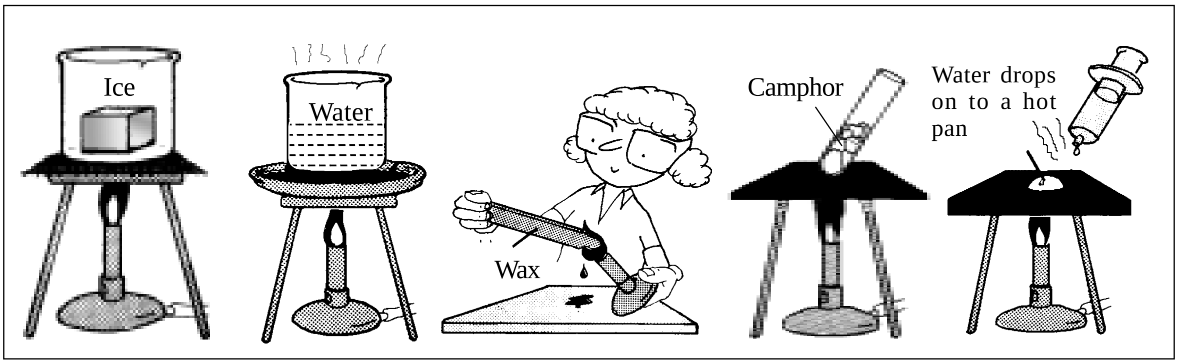


figure 1.1
Change of state occurs when substances are heated

Let us examine how the state of an object gets changed when it is heated.

You have studied in lower classes that all objects are made up of molecules and the heat supplied to it is utilised to increase the kinetic energy of molecules. Now let us see with the help of fig 1.1 what happens to them.

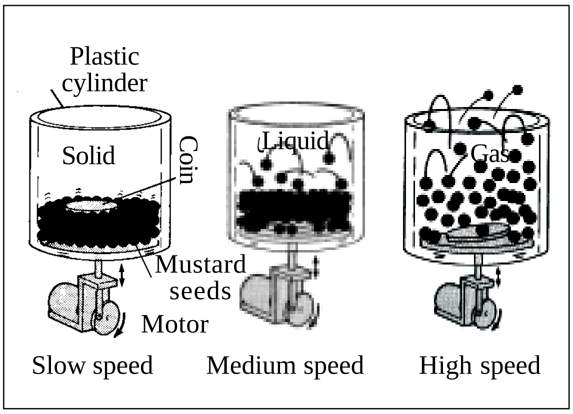
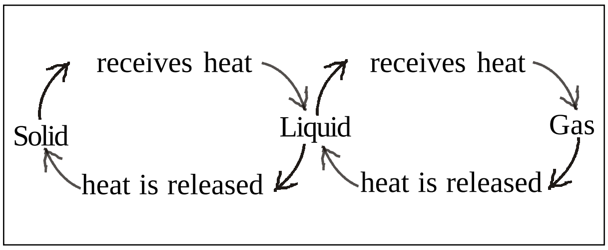


figure 1.2
Model to indicate the freedom of motion of molecules in solid, liquid and gas. The mustard seeds indicate the molecules.

Compare the motion of molecules in the three states of matter from fig 1.2. Can't you find out in which state of matter the molecules possess the maximum freedom of motion. The internal energy of the molecules is maximum at this state. This increase in internal energy is due to the heat energy that we supply.



You know that in the solid state, molecules are closely packed and therefore there is a large force of attraction among them.

When the substances are heated, the molecules in them will acquire more freedom to overcome the force of attraction. That is, when heated, solid is changed into liquid and liquid into gas.

Discuss, how a gas changes into a liquid and a liquid to a solid when the kinetic energy of the molecules decreases and write it down in the science diary.

1.05 Melting

With the help of an experiment we can understand how change of state occurs in an object when heated. Take some ice cubes in a beaker. Insert a thermometer into it and heat. After every two minutes note the temperature of ice cubes and its change of state.

Try to draw a graph by taking time on the X axis and temperature on the Y axis using the table 1.5.

Time in minutes	2	4	6	8	10	12	14	16	18	20	22	24	26
Temperature in °C													
Changes occuring in the ice cubes													

Table 1.5

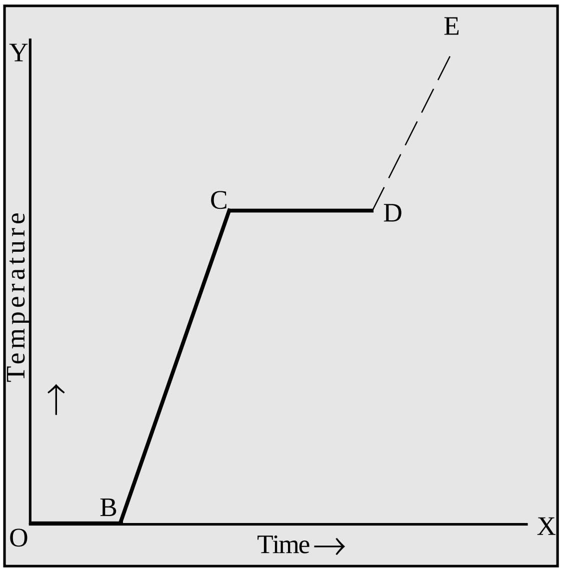


figure 1.3

Time - temperature graph of the continuously heated ice

Don't you get a graph as shown in Fig1.3?

Answer the following questions based on your experiments and observations

- What will be the state of ice cubes from O to B as represented in the graph?
- Even though heat is supplied during this time the temperature does not rise.
- If so, for what purpose was the heat utilized?
- What is the state of ice at B?
- For what purpose is the heat supplied from B to C utilized ? What is the state of the substance now?
- What is the state of the substance from C to D?
- Even though heat is given from C to D the temperature doesn't rise. If so for what purpose is the heat utilized?
- What is the state of the substance at D?

Note down in your science diary for what all purposes the heat given at different stages is utilized.

The fixed temperature at which a solid melts at standard atmospheric pressure is known as melting point. A liquid changes into solid also at this fixed temperature.

The quantity of heat absorbed by a solid of mass 1kg to change completely into liquid at its melting point without any rise in temperature is called its specific latent heat of fusion, (L_F). Heat required to change a body of mass m kg and specific latent heat of fusion (L_F) completely into liquid without any rise in temperature is mL_F.

Specific latent heat of fusion of certain substances are given below.

Substance	**Melting point °C**	**Specific latent heat of fusion (10^3J/kg)**
Mercury	-39	11.4
Hydrogen	-259	58
Silver	962	88
Ice cubes	0	335
Copper	1083	207

Table 1.6

Melting points and specific latent heat of fusion of certain substances

- 4kg silver at 962°C and 3kg copper at 1083°C are completely converted into liquid state without any change of temperature. Which one requires more heat? How much is this? (Specific latent heat of fusion of silver = 88×10^3J/kg and that of copper is 207×10^3J/kg)

Mass of silver = 4kg

Melting point of silver = 962°C

Specific latent heat of fusion of silver = 88×10^3J/kg

Heat needed to convert silver completely into liquid at its melting point=

mL_F = 4kg $\times$ 88 $\times$ 10^3J/kg = 352 $\times$ 10^3J

Mass of copper = 3kg

Melting point of copper = 1083°C

Its specific latent heat of fusion = 207×10^3J/kg

Heat required to convert copper completely into liquid at its melting point = mL_F = 3kg $\times$ 207 $\times$ 10^3J/kg = 621 $\times$ 10^3J.

Copper needs greater quantity of heat. The greater quantity of heat energy needed is $621 \times 10^3 - 352 \times 10^3 = 269 \times 10^3$J.

- If 2kg aluminium and 6kg copper are completely converted into liquid at their melting points 660°C and 1083°C respectively, which one requires more heat? How much? (Specific latent heat of fusion of aluminium is 390×10^3J/kg and that of copper is 207×10^3J/kg)

Given below is a list of situations in our daily life where the high specific latent heat of fusion of ice is utilised. Try to expand the list

- Ice cream does not melt quickly.
- Water in ponds and rivers doesn't became ice quickly.
- Ice cream at 0°C is felt to be colder than the drinking cold water at the same temperature.

Freezing mixture

A mixture having ice and common salt or ice and an impurity which dissolves in water is called freezing mixture. Its temperature is lower than 0°C.

A freezing mixture containing nitre (Potassium nitrate) and ice in the ratio 1:3 will solidify only if its temperature is lowered below -35°C.

A freezing mixture with ice cubes and calcium chloride in the ratio 3:4 reaches the solid state at -55°C.

Freezing mixtures are used for preparing ice creams and kulfi and for preserving biological specimens.

1.06 Regelation

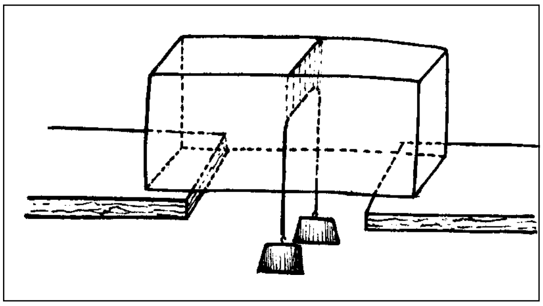


figure 1.4
A thin wire carrying weights at its ends is placed over a block of ice

A loop of thin wire with heavy weights attached to its ends is placed over a block of ice as shown in Fig 1.4. Observe what happens and note down your observations in the science diary.

When pressure increases melting point of ice decreases and ice melts. When pressure is removed the water thus formed solidifies. Thus the wire slips through the ice block without cutting it into two. This phenomenon is called regelation.

Let us examine how the phenomenon becomes helpful for a person who skates over ice flakes. A skater skates over ice flakes. Due to his weight the pressure between the shoe and ice flakes increases. Ice melts and a thin layer of water is formed. This helps the skater to move easily.

Press two pieces of ice together and remove the pressure after sometime. What happens now? Try to explain the results of your observations.

1.07 Latent heat of vaporisation

Look at the graph (1.3) relating to the heating experiment of ice. What is the significance of the portion C D? What do you learn from this? Even though heat is supplied continuously the temperature does not rise. For what purpose is this heat utilized? Is it not used for change of state? Hasn't the water changed completely into vapour at D?

The constant temperature at which a liquid boils and changes into vapour at standard atmospheric pressure is known as its boiling point.

The quantity of heat required to convert 1kg of a liquid completely into vapour at its boiling point without change of temperature is called specific latent heat of vaporisation (L_V).

If m kg of liquid of specific latent heat of vaporisation Lv is completely changed into vapour the heat required is equal to mL_v.

- Specific latent heat of vaporisation of some liquids is given in the table 1.7. From this we know that water has highest specific latent heat of vaporisation.

Substance	**Boiling Point**	**Specific latent heat of vaporisation 10^4 J/kg**
Methyl alcohol	64°C	112
Chloroform	61°C	25
Ethyl alcohol	79°C	85
Mercury	357°C	27
Turpentine	156°C	29
Water	100°C	226

Table 1.7
The boiling points and the specific latent heat of certain substances

The highest specific latent heat of vaporisation of water has a lot of benefits in our daily life. Find out such instances and list them.

- Helps to prevent the loss of water in the soil.
- Food items prepared in steam (Puttu, Idli etc) get cooked easily.
-

The burn caused by steam is more severe than the burn caused by boiling water of the same temperature. Say whether this statement is correct or not. Why?

- 100g steam at 100°C is allowed to condense at the same temperature and then it is cooled down to 30°C. Calculate the heat liberated during this process. (Specific latent heat of vaporisation of water is 226×10^4J/kg. Specific heat capacity of water is 4200J/kg°C).

Mass of steam = 100g = 0.1kg

Specific latent heat of vaporisation of water = $L_v = 226 \times 10^4$J/kg

Heat liberated during condensation = $mL_v = 0.1kg \times 226 \times 10^4$J/kg =

22.6×10^4J/kg = 226000J

Specific heat capacity of water = 4200J/kg°C

Heat liberated when 0.1kg of water is cooled from 100°C to30°C = mcθ

= $0.1kg \times 4200J/kg°C \times (100°C-30°C)$

= 420×70 = 29400J

Total heat liberated = 29400+226000 = 255400J

- Calculate the heat required to convert 10g of ice at 0°C to water at 30°C. (Specific latent heat of fusion of ice =335×10^3J/kg. Specific heat capacity of water is 4200J/kg°C)

Boiling point and pressure

You have seen that pressure influences the melting point of a solid. Let us do an experiment to see whether the boiling point of a liquid is also influenced by pressure.

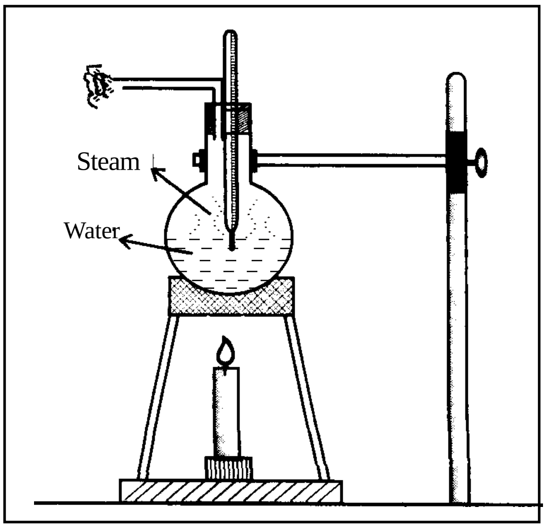


figure 1.5

Take some water in a flask. Close it with a two holed cork. Insert a thermometer through one hole and a delivery tube through the other. Heat the flask. Note down your observation in the science diary. When the water boils, partly close the open end of the delivery tube (remember the possibility of danger if closed completely). Now the pressure in the flask increases. Is there any change in the boiling point with the change in pressure?

Close the flask tightly and remove the flame and cool the flask using cold water. Then the temperature falls.

Accordingly the steam in the flask condenses and as a result the pressure decreases. Observe the water in the flask and also note the reading in the thermometer. What does this temperature indicate?

The boiling point of a liquid increases with increase of pressure and decreases with decrease of pressure. Now can you state why cooking food is easier in a pressure cooker?

1.08 Evaporation

Discuss and note down the reasons for the following statements.

- Wet clothes get dry even if hung inside a room
- A drop of spirit placed on a glass plate vaporises very soon
- Drop some spirit or ether on your hand: What do you feel then?

Wrap the bulb of a thermometer with a little cotton. Wet the cotton with ether or spirit and observe the temperature in the thermometer for a little while. Write down your inferences in the science diary.

Do the liquids boil in the above situations? Don't you see the liquid changing itself into vapour without boiling?

In the above situations, molecules escape from the surface of the liquid and as a result liquid gradually changes itself into gaseous state. It is a phenomenon that takes place slowly at all temperatures. This is evaporation.

During evaporation, the required latent heat is absorbed from the surface with which the liquid is in contact and cooling takes place at those regions of contact.

Given below are certain situations where evaporation is utilised in our daily life. Try to expand the list.

- Water taken in an earthen pot is cooler .
- Wet clothes dry quickly if spread out.
- Blowing of wind causes cooling during perspiration.

Discuss the above life related situations relating to evaporation and find out and list the factors that influence it.

- Surface area
- Temperature
- Wind

Refrigerator

It is a device which works on the principle that evaporation of liquid causes cooling. Low temperature is necessary to keep food from spoiling. Let us see how low temperature is maintained in a refrigerator

Haven't you noticed the tubes behind the cooling chamber of a refrigerator? (fig 1.6 a,b) A volatile liquid freon is circulated through this evaporation tube using a pump. This liquid reaching the evaporation tube through a valve undergoes evaporation. As it receives the heat required for evaporation from the cooling chamber, the chamber gets cooled. This vapour reaches the pump. Pump exerts pressure and converts it in to liquid again. Thus condensation takes place in the condensation tube fitted with copper fins. These copper fins radiate the latent heat given out by the condensing vapour. From the condensation tube the liquid is again sent to the evaporation coil

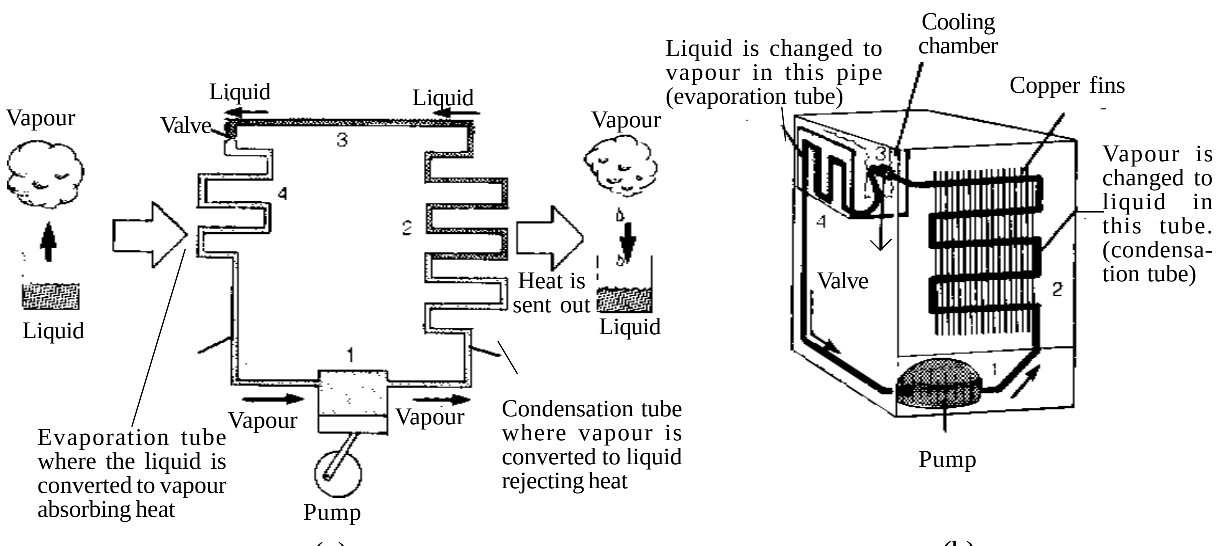


figure 1.6
Refrigerator

through the valve. This process continues and the cooling chamber is cooled down to the desired temperature.

Certain statements regarding boiling and evaporation are given below. From the statements select the appropriate ones and fill up the following table (1.8)

- Takes place at a fixed temperature
- Takes place at all temperatures
- Requires external energy
- Causes cooling
- Takes place quickly
- Takes place only on the surface
- Takes place slowly

Boiling	Evaporation
•	•
•	•
•	•

Table 1.8

1.09 Sublimation

Place a piece of camphor on a glass plate and heat it slowly. What do you observe? Note down the results of your observation.

The process of conversion of a solid directly into vapour when heated is called sublimation.

Can you explain why naphthalene balls (moth balls) disappear when exposed in air.

1.10 Relative humidity

Put some pieces of ice in a steel tumbler having a shining outer surface. Observe the changes that occur on the outer surface of the tumbler. Discuss the results of your observations and expand the list given below.

- The atmospheric air always contains water vapour.
- Heat required for the melting of ice is received from steel tumbler and the atmosphere. Therefore water vapour condenses.
-

The amount of water vapour in the atmospheric air is called humidity.

The ratio between the mass of water vapour in $1m^3$ volume of atmosphere and the mass of water vapour required to saturate the same volume is known as relative humidity at that atmospheric temperature. Generally relative humidity is expressed in percentage or fraction.

Hygrometer is an instrument used for measuring relative humidity.

Temperature of air in °C	Mass of water required to saturate $1m^3$ of air
10	9.3g
15	12.7g
20	17.1g
25	22.8g
30	30g
35	39.2g
40	51g

Table 1.9

One of the major factors that control rain is the amount of water vapour in the atmosphere. This is the importance of relative humidity in weather forecasting.

Summary

- **Heat capacity** - Heat required to raise the temperature of an object by 1°C.
- **Specific heat capacity (c)** - Heat needed to raise the temperature of one kilogram of a substance by 1°C.
- The heat required to raise the temperature of a substance of mass m kg by θ°C is $Q = mc\theta$
- **Principle of method of mixtures** - When a hot object and a cold object mix together the heat lost by hot object will be equal to the heat gained by cold object.
- **Change of state**- When a substance is heated the kinetic energy of the molecules increases and at a certain temperature change of state occurs.
- **Melting point** - The fixed temperature at which a solid liquefies at standard atmospheric pressure is called melting point.
- **Specific latent heat of fusion** - The quantity of heat absorbed by a substance of 1 kg for its complete conversion into liquid at its melting point without any change in temperature is called specific latent heat of fusion.
- **Regelation** - An increase of pressure reduces the melting point of ice. As a result ice melts. When pressure is removed the molten ice solidifies. This phenomenon is known as regelation.
- **Boiling point** - The fixed temperature at which a liquid boils and changes itself into vapour at standard atmospheric pressure is called boiling point.
- **Specific latent heat of vaporisation** - The quantity of heat absorbed by a liquid of 1 kg to completely change into vapour without any change in temperature at its boiling point is called specific latent heat of vaporisation.
- **Sublimation**- A phenomenon by which a solid directly changes into vapour when heated.
- **Humidity** - The amount of water vapour present in air.
- **Relative humidity** - The ratio between the mass of water vapour in a volume of $1m^3$ of atmosphere and mass of water vapour required to saturate the same volume is the relative humidity at that atmospheric temperature.

More activities for you

1. Common salt is sprinkled on ice-covered roads in cold countries. Can you explain the advantage of this?
2. Try to find out and explain the changes that occur to the volume of different solids when melted.
3. Even in summer water content in the soil doesn't lose easily. Find out the reason and make a note about this.
4. When dews form in the atmosphere its temperature slightly rises. Why?
5. Can you explain why there is difficulty in cooking food in open vessels at places of high altitudes.
6. Explain what happens when a very thin and sharp knife is pressed continuously into a block of ice?
7. In extremely cold places buckets of water are kept in rooms where vegetables are stored. This helps to maintain the quality of vegetables. Find out the scientific principle behind this.
8. Doctors suggest to keep wet clothes on the forehead of a person suffering from severe fever. What is the advantage of this?
9. Construct and exhibit a wet and dry bulb hygrometer.
10. Calculate the quantity of heat required to convert 100g water at 5°C to steam at 100°C (specific heat capacity of water is 4200J/kg°C and specific latent heat of vaporisation of water is 226×10^4J/kg)
11. An iron sphere of mass 3.36kg is heated to 100°C and placed on a large block of ice. Calculate the mass of ice melted(Specific heat capacity of iron = 460J/kg°C Specific latent heat of fusion of ice = 335×10^3J/kg)

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