Thermal Properties of Matter

Thermal Expansion

When matter is heated, the separation between molecules increases and matter expands

- Solids expand least as they require more energy due to strong force of attraction
- Liquids expand more than Solids due to force of attraction weaker as compared to Solids
- Gases expand most because of weak force of attraction between molecules

Uses of Thermal Expansion

- Bimetallic Strip



It is made up of two metals, one with higher thermal expansion and other will lower expansion. Bimetallic Strip bends when temperature reaches a certain value

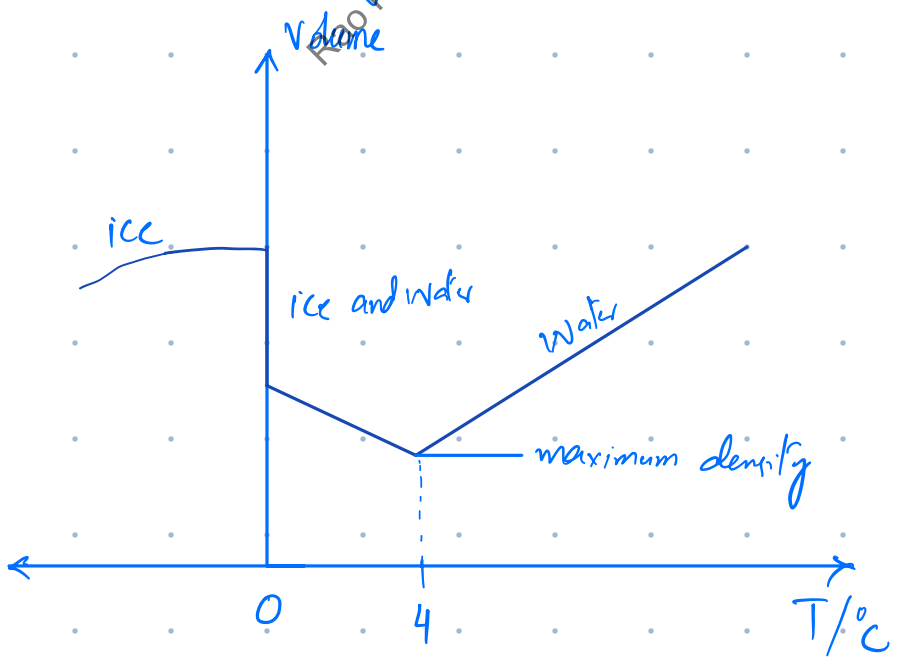
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- Railway tracks, bridges are tapered, joints are made to prevent heat expansion

- Electrical Cables are loosened so that they do not break when contract in winter

Unusual Expansion of Water

Water contracts maximum upto 4°C. It expands between 0°C and 4°C. So water has maximum density at 4°C



* Cold water (around 4°C) is more dense than ice So ice will float over it and a layer of ice will be formed on the surface (frozen lakes)

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Specific Heat Capacity

"Heat energy required to raise the temperature of a unit mass of a substance by one degree"

$$c = \frac{E}{m\Delta\theta}$$

$c \rightarrow$ Specific heat capacity

$m \rightarrow$ mass of object

$\Delta\theta \rightarrow$ change in temperature

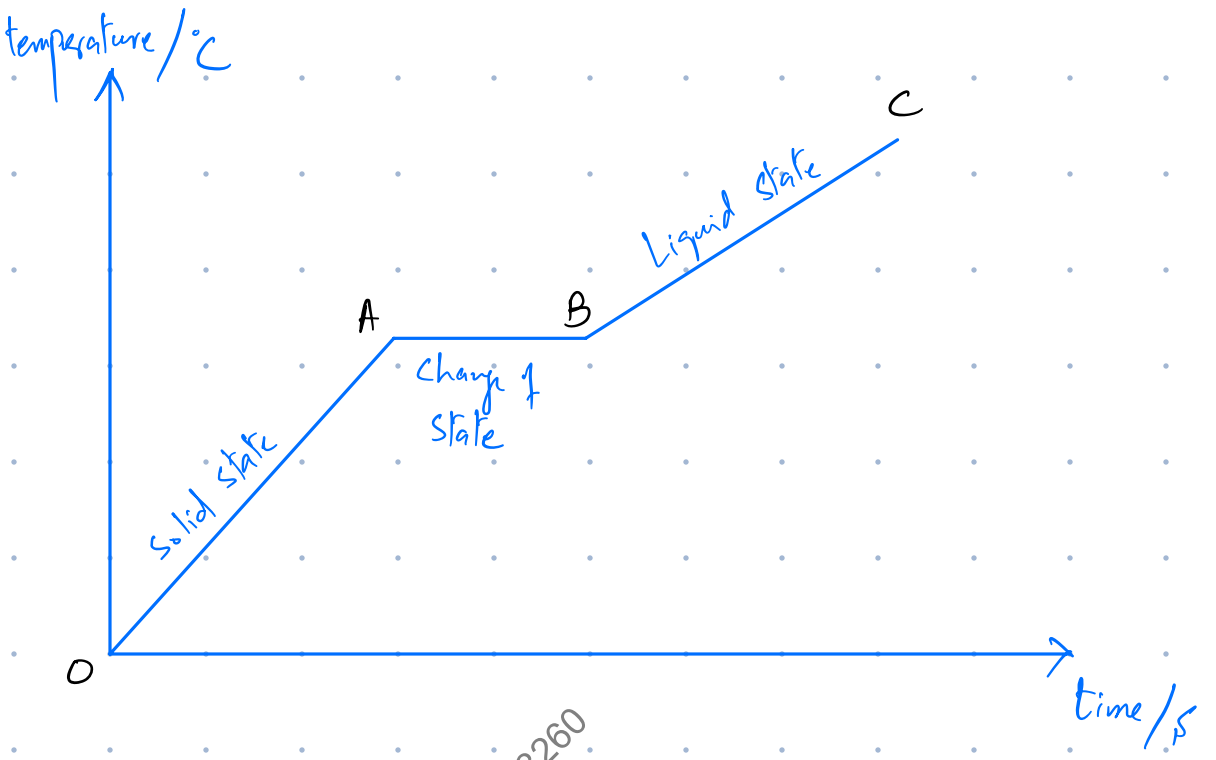
- unit of Specific heat capacity is $J\,kg^{-1}\,C^{-1}$

Note: Specific heat capacity c is material property

an object with larger specific heat capacity will require more energy to change its temperature

* Liquids have larger Specific heat capacity So their temperature change is slower

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* In the graph above, the gradient of BC is smaller than OA because in liquid state, specific heat capacity is higher (slow temperature change)

Example: Specific heat capacity of water is $4200\ J\ kg^{-1}\ C^{-1}$. Find the amount of heat energy required to raise the temperature of 20 kg water from 25°C to 80°C.

Solution:

$$\Delta\theta = 80°C - 25°C = 55°C$$

$$c = 4200\ J\ kg^{-1}\ C^{-1},\quad m = 20\ kg$$

$$\because\ E = mc\Delta\theta$$

$$= 20 \times 4200 \times 55 = 4.62 \times 10^{5}\ J$$

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Change of State

- When an object changes state, it absorbs energy but temperature becomes stable, the absorbed energy is used up to weaken intermolecular forces

Latent Heat of Fusion

Heat energy required by an object to change its state from Solid to liquid without changing its temperature.

Latent Heat of Vaporisation

Heat energy required by an object to change its state from liquid to gas without changing its temperature.

* Latent Heat is Thermal energy (Joules)

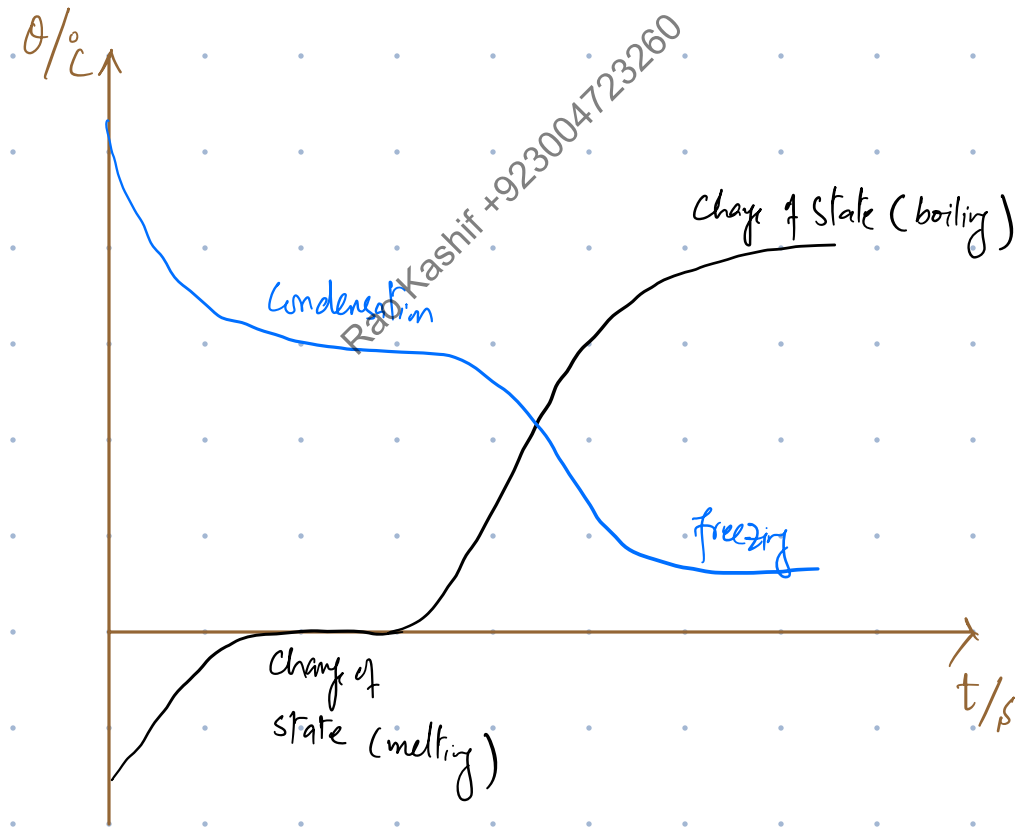
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Specific Latent Heat (l)

$$l = \frac{\text{Latent heat}}{\text{mass}} \quad (\text{J kg}^{-1})$$

"Heat energy required to change the state per unit mass without changing temperature"



Boiling & Evaporation

Boiling	Evaporation
• occurs at specific temperature (boiling point)	• occurs at all temperatures
• occurs throughout the liquid	• occurs only at surface
• Heating process	• Cooling process
• Bubbles are formed	• No bubbles are formed

However, both boiling and evaporation are change of state from liquid to gas

* Evaporation causes cooling because high energy particles leave the surface and surface temperature reduces

Factors effecting rate of evaporation

- Surface area : Large surface more evaporation
- Surface temperature : more evaporation at high temperature
- Speed of wind : Wind speed increases, rate of evaporation increases

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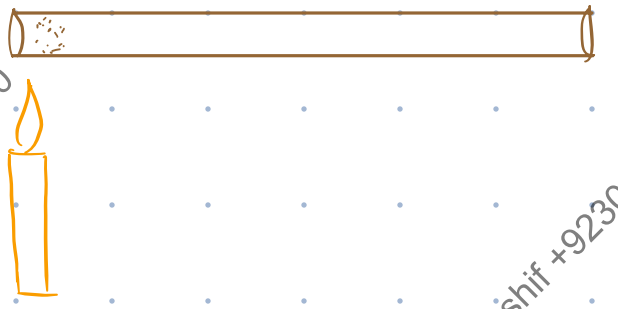
Heat Transfer

Conduction

"Heat transfer by vibrating particles"

Explanation

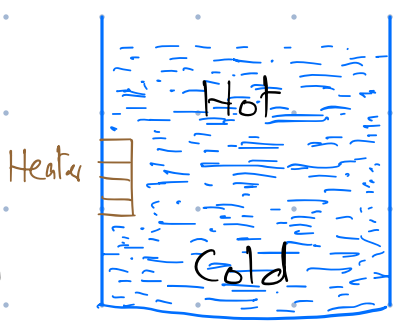
If a solid rod is heated at one end, the molecules vibrate more vigorously, they transfer their energy to neighbouring particles and so on, thus other end of the rod also gets heated



* Conduction is faster in metals due to free electrons which also act as carriers of energy

- Conduction is very slow in liquids and it is so slow in gases that is is almost no effective

* Water below heater remain cold for a long time due to slower conduction in liquids



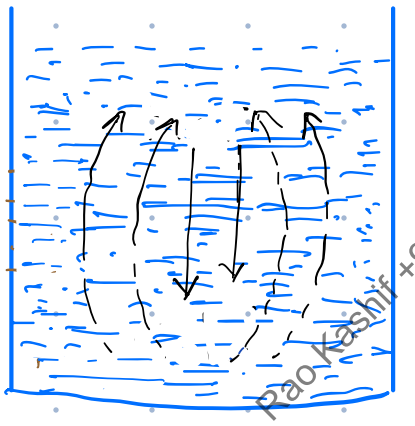
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Convection

"Heat transfer by actual movement of particles due to difference of densities"

Explanation

Conduction takes place in liquids and gases. When particles get thermal energy, they become less dense and rise upwards. Colder particles are more dense so they move downwards. This circulation of particles is known as convection current.





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Radiation

Heat Transfer by electromagnetic radiations (infrared radiations)

Explanation

Both Conduction and Convection are heat transfer methods involving particles but radiation does not involve particles or medium.

- Heat energy from Sun to Earth reaches by radiation
- Radiations are emitted from every hot object (a room feels more warm when more people are inside)

Factor effecting radiation

- Dull black: good emitter, good absorber of radiations
- Shiny silver: good reflecter, poor absorber
- large surface area also effects emission and absorption of radiation

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Solved Past Papers

22 How is heat energy transferred through the vacuum of space from the Sun to the Moon's surface?

A conduction only

B convection only

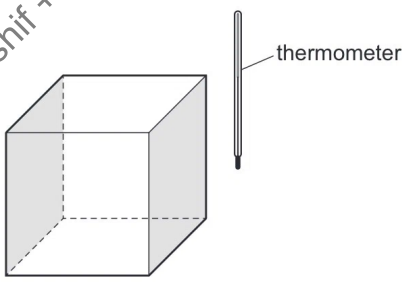
C radiation only

D conduction, convection and radiation

5054/12/M/J/22/Q16

23 A metal cube contains boiling water.

Each vertical face of the cube is painted a different colour or has a different texture.



Identical thermometers are held at equal distances from each vertical face.

Near which face does a thermometer read the greatest temperature?

A dull black

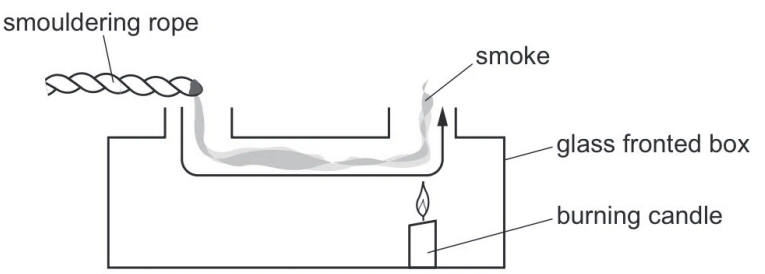
B dull white

C shiny black

D shiny white

* dull black emits radiation most

12 When a piece of smouldering rope is held at the opening of the box in the diagram, smoke moves in the direction indicated.



What is responsible for the movement of the smoke?

A convection

B movement of free electrons

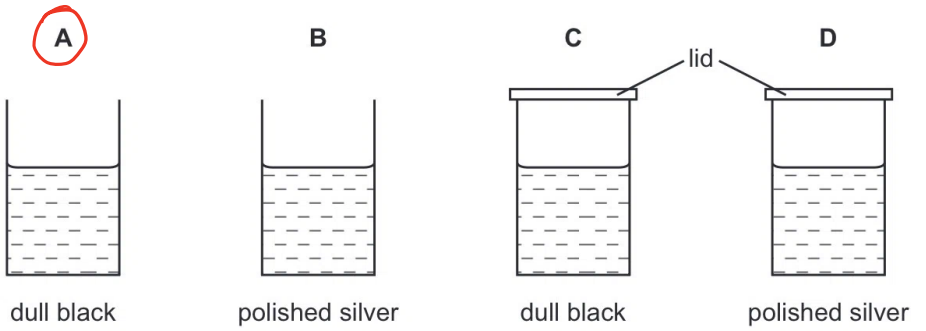
C radiation

D vibration of molecules

5054/11/M/J/18/Q20

13 The diagrams show four identical cans with their outside surfaces either polished silver or painted dull black. Each can contains the same volume of water, initially at 80 °C.

After five minutes in a cool room, which can contains the coolest water?



5054/11/M/J/18/Q21

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7 Liquid air contains a mixture of oxygen and nitrogen.
The boiling point of nitrogen is –196 °C and the boiling point of oxygen is –183 °C.
A sample of liquid air in a beaker is allowed to warm up slowly.
Fig. 4.1 shows how the reading of a thermometer in the beaker varies with time *t*.

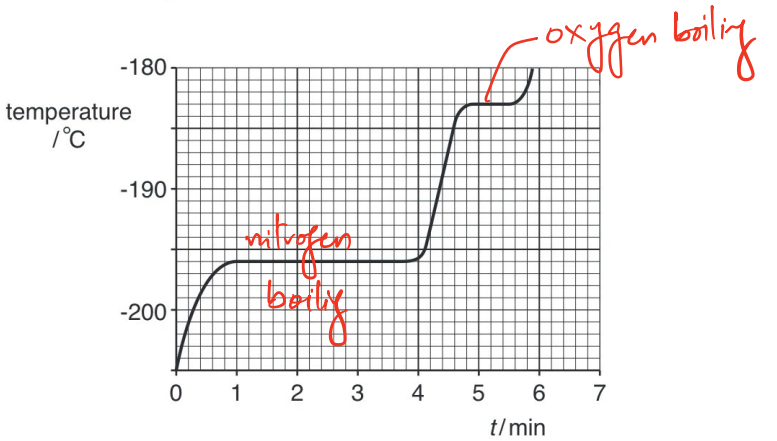


Fig. 4.1

(a) Describe the two changes of state that occur and state when they occur.

liquid nitrogen starts boiling at −196°C (start changing from liquid to gas) from 1 sec to 4 sec

..... [3]

(b) The liquid air contains 200 g of liquid oxygen and 800 g of liquid nitrogen.
The specific heat capacity of liquid oxygen is 1.7 J/(g °C) and the specific heat capacity of liquid nitrogen is 2.0 J/(g °C).
Calculate the thermal energy needed to warm the liquid from –205 °C to –196 °C.
State the formula that you use in your calculation.

$\Delta\theta = -196 - (-205) = 9°C$

$E = mc\Delta\theta$

For oxygen:

$E = 200 \times 1.7 \times 9$

$= 3060\ J$

for nitrogen

$E = 800 \times 2 \times 9 = 14400\ J$

energy = ... [4]

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