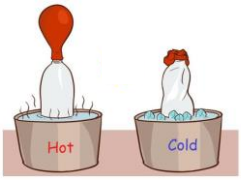
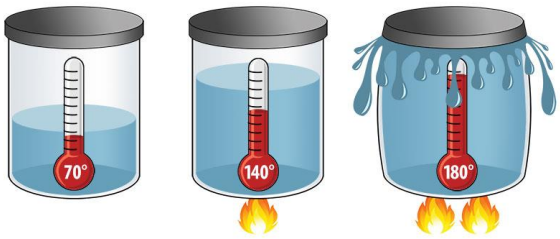


THERMAL EXPANSION

PROPERTIES OF MATTER

Introduction.

- The word thermal.
- Temperature.
- Temperature and heat
- Thermal expansion in solids
- Thermal expansion in liquids
- Thermal expansion in gases
- Expansion of water
- Application of thermal expansion



Thermal

- The word **thermal** refers to anything related to **heat** or **temperature**. The word thermal can refer to the transfer, storage, or management of heat energy.
- In JCE we learned that when most substances are heated they increase in size or volume, and we call this process **expansion**.
- The same substance will decrease in size upon cooling and the process is called **contraction**.
- In this topic we will discuss thermal expansion for all the three states of matter in terms of **particle behaviour**.

***Figure 1**: States of matter*

Temperature

- Temperature is the ***degree of coldness or hotness of a given body or substance***.
- From the kinetic theory of matter, we all know that the particles of a substance are always in random motion and that the energy that causes this random motion is called **kinetic energy (K.E)**.
- K.E is affected by the changes in the surrounding temperature, in such a way that; when temperature increases the K.E also increases and this results in molecules of a substance moving ***faster than before***.
- When the temperature decreases the kinetic energy also decreases resulting in a reduced motion of the molecules.
- As a result, temperature can also be defined as ***the average kinetic energy of the molecules of a substance***.
- The **SI unit** of temperature is ***kelvin (K)***, but the most commonly used one is ***degrees Celsius (°C)***.

Difference between Temperature and Heat

We can differentiate temperature and heat in the following ways:

- Heat is a **form of energy** which passes from a body of **high temperature** to a body of low temperature, while temperature refers to the **degree** of **hotness** or **coldness** of a given body.
- The **SI unit** of heat energy is the **joule (J)**, while, the **SI unit** of temperature is the **kelvin (K)**.
- Temperature is a **scalar quantity**, while heat is a **vector quantity**.
- Heat is measured using a device like a **calorimeter** while, temperature is measured using a **thermometer**.

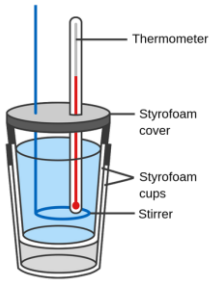


Figure 2: *Constant pressure calorimeter*

Thermal Expansion in Solids

- This is when a solid material gets bigger when it is heated and smaller when it is cooled.

Particle behaviour during thermal expansion in solids

- The particles in solids are closely packed and they are always in continuous vibration about their fixed positions. When heated the particles vibrate with larger amplitude about their fixed positions. This result in the particles colliding with each other with larger forces which push them far apart.
- The distance between the molecules increases as a result we say the solid has expanded.
- **Figure 3** below shows a Metal ball **before** (a) and **after** being heated (b).

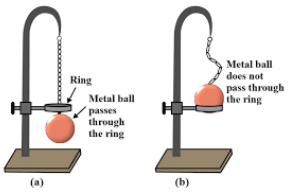


Figure 3*: expansion and contraction in solids*

Demonstrating Thermal Expansion in Solids

The materials that will be required are:

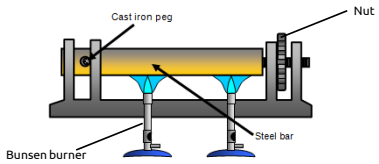
- Cast iron bar breaker (Steel bar with a hole).
- Bunsen burners.
- Thin cast iron rod.

Procedure

a. Fix the steel bar in the frame of the bar breaker.

b. Lock the steel bar on the frame by inserting the thin cast iron rod in the hole on the steel bar.

c. Heat the steel bar strongly using the Bunsen burners and observe what happens to the cast iron rod.



- On cooling the steel bar, the cast iron rod breaks.
- This shows that as the steel bar **contracts** it pulls the cast iron rod against the inner frame of the bar barker, as a result the rod breaks.
- This shows that solids **expand** on heating and **contract** on cooling.

Thermal Expansion in Liquids

- This refers to the tendency of a liquid substance to **change in volume** (expand or contract) in response to changes in temperature.

Particle behaviour during thermal expansion in liquids

- Liquid molecules are loosely packed and move freely. The **IMF** between the molecules is weaker as compared to that in solids.

**** IMF – Intermolecular Force***

- On heating, the speed of the molecules in liquids increases. This leads to increased collisions between the molecules which in turn increase the distance between the molecules, resulting in the increase in volume (expansion) of the liquid.

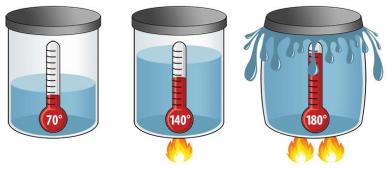


***Figure 4**: expansion in liquids*

Demonstrating Thermal Expansion in Liquids

The materials that will be required are:

- Water bath
- Paraffin, Alcohol, Water.
- Heater
- Three similar test tubes with fitted similar capillary tubes through the corks.

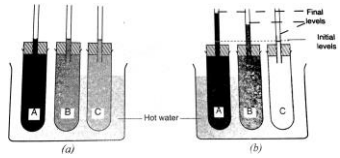
Procedure

a. Label the three test tubes as **X**,**Y**, and **Z**, and fill them alcohol, paraffin and water respectively.

b. Cork the test tubes and put them in the a water bath as shown in the figure.

c. Heat some water to boiling point and pour it in the water bath and stir to ensure even distribution of heat to the test tubes.

d. Observe the level of the liquids in the test tubes after 3 minutes.



- At first the level of the liquids in all test tubes falls slightly, then start to rise again up the capillary tubes.
- Alcohol rises to the highest level followed by paraffin, then water.
- Heat from the water bath reaches the test tubes first, making the test tubes to expand, hence the liquid levels falling.
- Liquids expand on heating and contract on cooling.

Thermal Expansion in gases

- This refers to the to the increase in volume that occurs when a gas is heated.

Particle behaviour during thermal expansion in gases

- The distance between the molecules in gasses is very large as compared to those in solids and liquids. The IMF between the molecules of a gas are very weak hence, the molecules of a gas move freely in all directions.
- When a gas is warmed up (heated) the molecules gain kinetic energy and move fast and far apart than before hence the volume of the gas increasing.

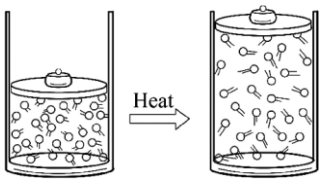


***Figure 5**: expansion in gasses*

Demonstrating Thermal Expansion in Gases

The materials that will be required are:

- Thin glass flask
- Rubber band
- A balloon
- Water bath, Source of heat

Procedure

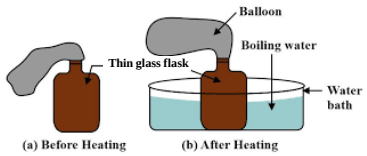
a. Fit the balloon at the mouth of the thin glass flask and tie it using the rubber band as shown on **figure a**.

b. Immerse the thin glass flask in the water bath.

c. Heat the apparatus on a tripod stand.

•On heating the balloon inflates, snice the air in the glass flask expands, increasing volume in flask and in the balloon, hence inflating it.

•As a result we can say that gases expand on heating and contract on cooling.



Expansion of water

•Water behaves in an **unusual** or **abnormal** way, in the sense that when it is heated it **does not** always **expand**.

•This unusual behaviour of water is what we call **anomalous** or **abnormal** expansion of water.

•Abnormal expansion of water refers to the decrease in volume (contraction) of water as the temperature rises from **0 °C** to **4 °C**.

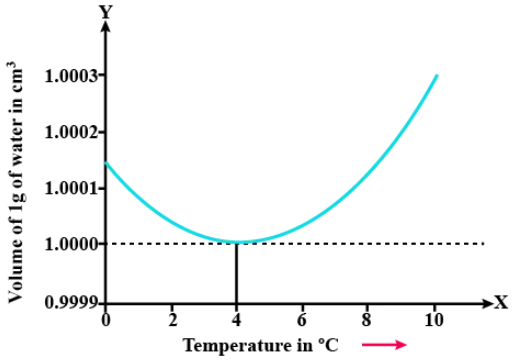
•Beyond 4 °C, water then expands likes all other liquids.

•This shows that for a fixed mass of a body of water will have a minimum volume and maximum density at 4 °C.

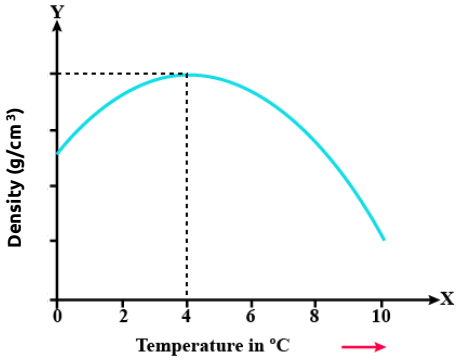
•Below are graphs showing the relationship of water, temperature, and density. (Check next slide)

Expansion of water

A GRAPH OF VOLUME AGAINST TEMPERATURE.



A GRAPH OF DENSITY AGAINST TEMPERATURE OF WATER



Effects of Unusual Expansion of water

•Bursting of water pipes.

- If water flowing flow pipes cools from 4 °C to 0 °C and freezes to ice, the pipes can burst since the volume of water increases.

•Weathering of rocks.

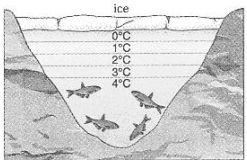
- When water freezes in cracks of a rock, the volume of water increases on cooling from 4 °C to 0 °C. This causes the rock to break into smaller pieces.

•Breaking of water bottles in freezers.

- If no space is left is a water bottle which is put in a freezer, the bottle will burst since the volume of water increases when cooling form 4 °C to 0 °C.

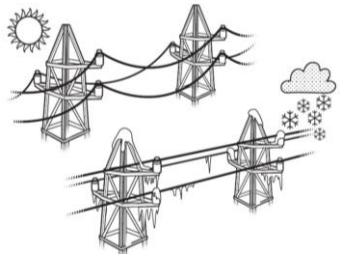
•Survival of aquatic organisms in freezing lakes and ponds.

- As the temperature of water above the lake or pond decreases from 10 °C to 4 °C, the density of water increases. This dense water sinks to the bottom of the lake or pond and remain in liquid form allowing plants and animals to survive, while the less denser water rises to the top of the lake or pond and freezes at 0 °C to form ice.



Application of Thermal Expansion & Contraction

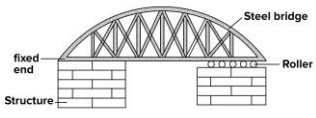
- **Loose fittings of electrical cables.**
  - Electrical wires are loosely fit to allow expansion during hot days and contraction during cold days.



- **Separation of stuck tumblers/glasses.**
  - Stuck tumblers can easily be separated by placing them upright in a warm water bath and pouring cold water into the inner tumbler. This makes the outer tumbler to expand while the inner tumbler contract, making it easy for the tumblers to be separated.
- **Removing of tightly screwed covers**
  - Hot water is poured on bottle top or container covers while the bottle or container is in cold water. This makes the lid to expand while the bottle or container contracts, making it easy to remove the lid.

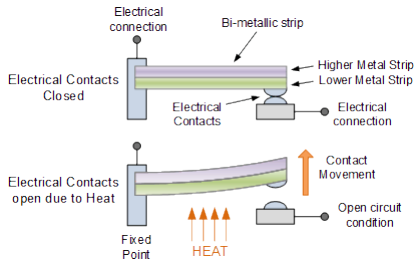
Application of Thermal Expansion & Contraction

- **Gaps in railroad tracks.**
  - Railroad tracks are laid with small gaps between sections to account for thermal expansion and prevent buckling or warping of the tracks in hot weather.
- **Expansion gaps in fences.**
  - Expansion gaps are created in walls to allow room for expansion of the bricks or blocks during hot weather.
- **Rollers on bridges.**
  - The ends of steel and concrete bridges are supported on rollers. During hot or cold weather, the changes in length of the steel bridge may take place freely without damaging the structure.



Application of Thermal Expansion & Contraction

- **Shrink fitting.**
  - This is a method used to make mechanical joints when tubes or axles are to be fitted inside other hollow tubes or parts.
  - The hollow tube is heated to expand, while still hot, the axle is fitted, during cooling the, the hollow part contracts making a tight grip around the axle.
  - This method is also used in **rivets**.



Questions.

a. Define the term temperature. (1)

b. Give any **two** differences between heat and temperature. (2)

c. Convert 546 K to degrees Celsius. (3)

d. Describe how expansion and contraction of metals is used in shrink fitting. (3)

e. Explain what is happening in the graph below and give valid reasons for your answers: (5)