Calorimetry

What does heat do to matter? Ever thought about it? If you had all the ice-cream in the world, how big or powerful refrigerator would you require to keep it frozen? That is what we study in Calorimetry. From ice-creams to the inside of a star, let us see how warm our Universe really is!

What is Calorimetry?

'Calorimetry' is the branch of science which measures the changes in the heat energy of a body. We all know that heat is a form of energy. The amount of heat in a body is indicated by its temperature. Therefore, greater the temperature, more is the heat energy of a body. Hence, to know if a body has gained heat energy or lost it, we measure the temperature of the body before and after the transfer. This difference in temperature determines the change in heat energy of the body.

Suppose you make a cup of coffee while studying this topic or you grab an ice-cream. Initially, the coffee is hot and steaming and its temperature is about 80^{0}C . Now assume you have a friend come over at your place and you begin chatting with him.

In this process, an hour passes and the coffee cools down or the ice-cream melts. But why does this happen? This happens because the coffee loses its heat energy to the surroundings and its temperature drops. In case of the ice-cream, it gains heat from the surroundings and its temperature raises. So the new temperature range lies in the range of 30-40 ^{0}C.

So, where did the heat energy initially present in the Coffee cup go? And where did the energy that melts our ice-creams come from?

Obviously, the heat energy of the coffee cup is transferred to the surroundings. The same surroundings are responsible for melting our ice-cream too! This is exactly the premise of the topic of Calorimetry. Mind you, this topic deals only with the transfer and conversion of 'Heat' energy into other forms of energy like work and vice versa.

System

The body which is under study, on which work is being done or to which heat is being added or which is doing work, or giving out heat is a 'System'. A System has a fixed amount of mass and has a definite boundary. For example, in the example above the coffee cup is the ' System' under study.

Boundary

The 'Boundary' is a real or an imaginary surface, either movable or stationary which separates a system from the surroundings. In the example discussed above, the surface of the coffee cup serves as a real boundary.

Surroundings

The region around the system outside the boundary is the "surrounding". For the purpose of the study, we assume the entire universe separated from the system by the boundary as the 'Surrounding'.

Specific Heat

'Specific heat' is a property of a substance like density, boiling point etc. We define it as the amount of heat that we add to raise the temperature of a unit mass of the substance through 1 degree. We measure it in Joules/gm K or Joules per gram degree Kelvin and denote it by the letter C. For eg: The Specific Heat of water is 4.1813 J/gm K.

Change in temperature (ΔT)

The change in temperature is the modulus of the difference between the initial and final temperatures of the system. We denote it by $\Delta T = (T_{final} - T_{initial})$

Total Heat Energy (Q)

'Q' is the symbol used to denote the total heat exchanged by the system. We have $Q = mC\Delta T$; where m is the mass of the system.

Example 1: What is the amount of heat required to change the mass of 1 g of water by 30 °C. Given that C of water is 4.2 J/gm K.

Solution: Given: m= 1g;C=4.2J/gm K; ΔT=30

We know that heat energy required Q= $mC\Delta T$

Therefore Q= $1 \times 4.2 \times 30$ = 126 Joules.

Thus we have covered here the basics of Calorimetry. This subject finds a lot of application in modern physics, chemistry and their applications. Therefore, Heat transfer during various Physical and Chemical changes is studied in Calorimetry.

More Solved Examples For You

Example 2: The branch of physics that deals with the measurement of heat energy is known as:

A) Fermentation B) Latent Heat C) Calorimetry D) Hidden Heat

Solution: C) Calorimetry is the branch of Physics that deals with the measurement of heat energy. Calorimetry is one of the methods for the determination of specific heats or latent heats of the substances.

Example 3: On which law is the study of calorimetry based?

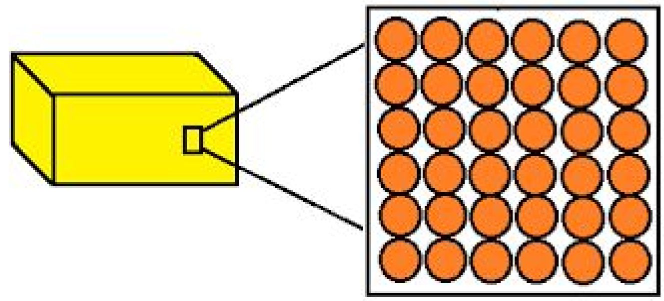
A) Joule's Law B) Law of Conservation of Energy   C) Law of Kinetic Energy   D) None

Solution: B) The Calorimetric studies are wholly based on the law of conservation of energy. Hence, if energy were not conserved, we would never be able to measure heat with a practical level of certainty.

Change of State

Do you ever observe what happens when ice melts? Have you noticed that water exists in all three states of matter? Do the States of matter like solid liquid gas have any relations? What is the role of temperature in changing the states of matter? Let us find out here.

Solid Liquid Gas



Let us start by describing the states of matter. In solids, the molecules are very close to each other. They have strong forces of attraction. As seen in the above example, the atoms in the solid lie neatly in planes in a definite orientation. Solids display high density, long-range structural order and characteristic rigidity with resistance to change in volume. They have comparatively good conductivity and heat conduction ability.

To convert a solid into a liquid you need to heat the solid beyond its melting point. The atoms absorb this heat and vibrate more and more. Hence, the atoms of solid move apart and ultimately it starts to flow. The melting point depends on the atmospheric pressure, the purity of the substance etc. This marks a change in the states of matter.

Browse more Topics under Thermal Properties Of Matter

- Calorimetry
- Heat Transfer

- Ideal Gas Equation and Absolute Temperature
- Newton's Law of Cooling
- Specific Heat Capacity
- Temperature and Heat
- Thermal Expansion

Liquids

The intermolecular forces of attraction amongst liquids are weaker than those amongst solids hence liquids do not have a definite shape but the forces are strong enough so that liquids have a definite volume. Liquids display properties like viscosity, flow, etc. They are comparatively more compressible as compared to solids.

To convert liquids into gas you need to heat the liquid beyond its boiling point. This process is the process of 'Boiling' or ‘vaporization’. Hence, to convert a liquid to a solid we cool it below its freezing point. This process is known as ‘Freezing’. During vaporization or freezing, the constituents of the liquid are in thermal equilibrium with the constituents of the other states (gas or liquid).

Gas

The molecules of a substance in this state have the least intermolecular forces of attraction amongst them. Gases display properties like dispersion and compression. To convert gases to liquids we cool them below their boiling point. This process is the process of ‘Condensation’.

When a change in state is going on, the thermal dynamics of the system get very interesting. For example, if you keep heating a substance, it changes its state with the absorption of temperature. But the absorption of temperature is not uniform. Let us see how it happens!

Latent Heat

When the change of state is studied carefully, we see that the temperature of a substance remains constant during a change in the state! This is very strange. As if the change in state opens up new portals or spaces where our supplied energy hides. Therefore we call this hidden energy, the latent or the hidden heat. Let us understand this with an example:

Suppose we have a block of ice we want to convert to water. We all know that ice turns to water and vice versa at 0°C. Now assume we start heating ice at 0°C. You will observe that when we do so, the temperature of ice does not change. It starts converting to water but the temperature does not rise until the entire ice block has been converted to water. But we are heating the ice block right? So, what happened.

If a mass 'm' of any substance undergoes a change in state by absorbing an amount of heat, Q at a constant Temperature T, then we have:

$$L = Q/m \text{ or } Q = mL$$

All the heat supplied to the ice at 0 ^{0}C is used by the ice to change its phase from solid to liquid. Thus the heat supplied is not used up to raise the temperature of the substance. There are 2 kinds of Latent heat:

Latent Heat of Fusion

The heat energy supplied per unit mass of a substance at its melting point to convert the state of the substance from solid to liquid is known as Latent heat of Fusion. Latent heat of Fusion of water is 334 Joules/gram of water.

Latent Heat of Vaporization

The heat that a substance absorbs per unit mass at its boiling point to convert the phase of the substance from liquid to gas is the Latent heat of Vaporization. Latent heat of Vaporization of water is 2230 Joules/gram of water.

Now similarly, if you want to convert the phase of a substance from a gas to liquid or from liquid to solid you need to cool the substance to its boiling point or melting point as the conditions demand and then extract the amount of Latent heat to facilitate the phase change.

Solved Examples For You on the States of Matter

Q 1: 20g of ice and 20g of hot water are mixed when the ice has melted the temperature of the mixture was found to be 0^oC. The temperature of hot water taken should be (L_{ice} = 80 cals/g):

A) 40 ^0C B) 72 ^0C C) 80 ^0C D) 96 ^0C

Solution: C) 80 ^0C – Assuming that the initial temperature of water = 0 ^0C

Heat lost by the hot water = heat gained by the ice

Therefore, $m_1c_1\Delta T_1 = m_2L$

$(20)(1)(T-0) = 20(80) = 80\ ^0C$.

Heat Transfer

Did you know that heat could be transferred between two bodies at different temperatures? In this discussion, we will look into the thermal properties of matter and will discuss various methods of Heat Transfer. We will also learn how to solve problems based on this concept.

What is Matter?

We know that matter is defined as anything which has a mass and occupies some space. Matter exists in 4 forms which are solid, liquid, gas and plasma.

What is Heat?

Heat is a form of energy. It derives its origins at the molecular scale. Molecules of a substance vibrate at their positions either fixed or not when energy is supplied to them. As they vibrate they transfer their energy to the surrounding molecules causing them to vibrate as well.

This kinetic energy builds up on a macro level as more and more energy is supplied to these molecules of the substance. As a result, when this energy reaches a threshold (eg. Melting point, Boiling point) do the molecules or atoms free themselves from interatomic forces of attraction and conversion of a state i.e. phase change takes place.

Heat energy of a body can also be defined as a form of energy that can be transferred from one body to the other or within the body itself with a temperature difference and can be generated by a body at the expense of other forms of energy. The SI unit of heat energy is Joule abbreviated as 'J'. In CGS system, however, heat is measured in 'Calorie' (Cal.) where 1 Calorie = 4.186 J

Browse more Topics under Thermal Properties Of Matter

- Calorimetry
- Change of State
- Ideal Gas Equation and Absolute Temperature
- Newton's Law of Cooling

- Specific Heat Capacity
- Temperature and Heat
- Thermal Expansion

What is Temperature?

The temperature of a body is the measure of the amount of heat content possessed by it. It is measured in degree Celcius (°C) or Kelvin(°K). The temperature of a substance is a physical quantity that measures the degree of hotness or coldness of a body.

Thermal Properties of Matter

The properties of the matter involving heat transfer and measurement are known as 'Thermal Properties of Matter'

Heat Transfer

Heat energy can be transferred from one body to the other or from one location in a body to the other. Study of the techniques and methods adopted to transfer heat energy is known as 'Heat Transfer'. To facilitate heat transfer between 2 bodies there needs to be a temperature difference between them.This means that these bodies must be a 2 different temperatures one higher than the other to allow heat to flow from one body to the other.

This means that no heat transfer occurs between 2 bodies which are at the same temperature. At the same time, it is very important to note that heat only flows from a body at higher temperature to a body at a lower temperature. Although this may look obvious, this law is very important from the point of view of thermodynamics.

Case Study: Cup of Tea

Let us say that you have prepared a cup of tea for yourself. The tea is very hot say at 80°C and so you leave it in a room with a temperature of 25 ° C for some time to cool down. This is the first law of heat transfer. Heat transfer will only take place between 2 bodies when they have a substantial temperature difference.

Now, after some time you come back to find that the tea in the cup has cooled down to say 50°C and you have a sip of the same. This is the second law of heat transfer. Heat will only flow from a body at higher temperature to a body at a lower temperature. It is not possible to have a scenario where the heat flows from the room at 25° c to the cup of tea at 80° C and heat it even further.

These techniques and methods discussed below are observed in nature and thus have been generalized for all things while under consideration for the purpose of the study. However, no observation against these has been ever recorded or observed thus establishing their credibility as truthful and applicable at all times.

Heat transfer takes place in 1 of the three ways namely: Conduction, Convection and Radiation We will discuss each of these methods in detail.

Conduction

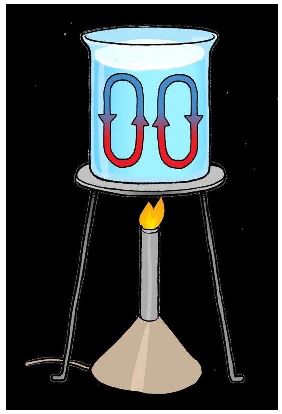
Conduction is the method of transfer of heat within a body or from one body to the other due to the transfer of heat by molecules vibrating at their mean positions. The bodies through which the heat transfer must be in contact with each other. There is no actual movement of matter while transferring heat from one location to the other.

Conduction occurs usually in solids where molecules in the structure are held together strongly by intermolecular forces of attraction amongst them and so they only vibrate about their mean positions as they receive heat energy and thus pass it to the surrounding molecules by vibrations.

Convection

Convection is the mode of heat transfer which occurs mostly in liquids and gases.In this method, heat transfer takes place with the actual motion of matter from one place within the body to the other. Often when we boil water we have seen bubbles and currents develop in the water on careful observation.

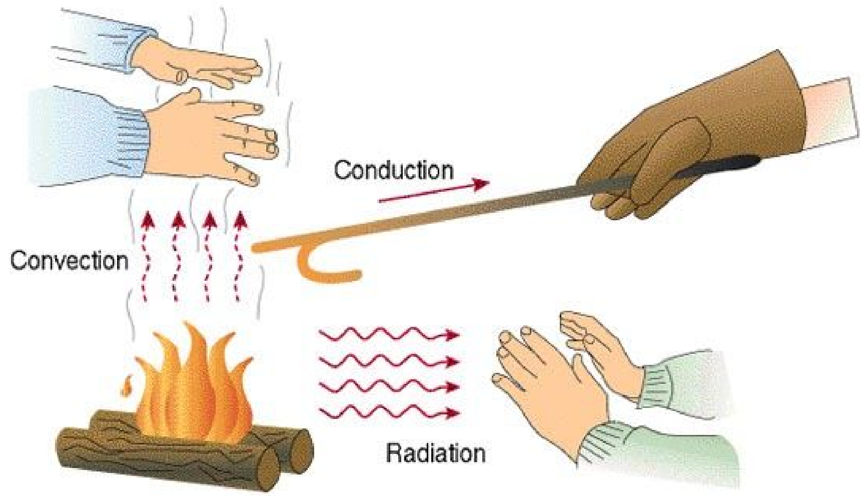
This is an apt example of the convection process. The hot water at the bottom becomes lighter and moves upwards forcing the cold and denser water at the top to come down and thus get heated up.



Radiation

Radiation is another form of heat transfer. It does not require any medium and can be used for transfer of heat in a vacuum as well. This method uses electromagnetic waves which transfer heat from one place to the other. The heat and light from the sun in our solar system reach our planet using radiation only.

In fact, radiation is the most potent method of heat transfer. In winters when we sit near a fire we feel warm without actually touching the burning wood. This is possible by radiation only.



The above example effectively demonstrates the 3 methods of heat transfer we have discussed above. Another important point while discussing heat transfer is as follows:

Suppose an object has to be cooled down in relation to the ambient temperature. How would you determine the amount of time required for a given article to acquire the ambient temperature? The answer to that is given by 'Newton's law of Cooling'.

Newton's Law of cooling

Newton's law of Cooling states that there is always a direct correlation between the rate of change of temperature of a body and the temperature difference between the object and the surroundings. What this simply means is a hot body will cool down faster if the temperature of the body is much greater than that of the ambient. Whereas another body which has a temperature that is closer to the ambient temperature will take a little more time.

For example, A cup of tea at 80° Celcius loses heat at a much faster rate to a surrounding at a temperature of 25°Celcius as compared to a cup of tea which is at 35° Celcius. This brings us to the end of our discussion. A thorough knowledge of these concepts will go a long way to help the reader understand concepts of heat transfers, thermodynamics, and their applications as well.

Solved Examples for You

Question: Two rods of the same length and transfer a given amount of heat 12 Second, when they are joined as shown in figure (i) But When they tire joined as shown in figure (ii), then they will transfer same heat in same. conditions in

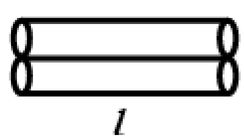


Fig. (i)

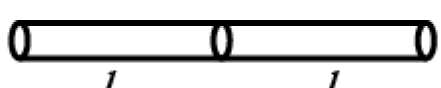


Fig. (ii)

A. 24 s

B. 12 s

C. 6 s

D. 48 s

Solution: Option (D) 48 s. We know that heat flow is given as: Q =

KAΔT

L

If they are connected parallel to each other, t α

L

A

Now, if they are connected in series then: t’ α

2L

A

2

So, t’ = 4 × t = 4 × 12 = 48 seconds

Ideal Gas Equation and Absolute Temperature

Hello Friends! Today we will look into and discuss the Ideal gas equation. We will also learn and understand the definition of Absolute Temperature and its utility in the study of Thermal properties of matter. Let us also learn what Boyle’s law is. So let us begin with the basics.

Ideal Gas Equation

To understand the ideal gas equation we will have to be clear the concepts given below.

What is an Ideal Gas?

An ideal gas is a theoretical gas! It does not exist in reality but is assumed to exist for the purpose of simplifying calculations. It also generates a reference point in relation to which the behavior of other gases can be studied.

An ideal gas is defined as a gas composed of randomly moving particles as all gases do, the only difference being that for an ideal gas when its particles collide with each other, these collisions are assumed to be perfectly elastic which means no energy of either of these particles is wasted.

In reality, however, when actual gas particles collide with each other, some of their energy is wasted in changing directions and overcoming friction. However, at STP (defined below) conditions most natural gases act just like an ideal gas subjected to reasonable restrictions.

Generally, any gas behaves similarly to an ideal gas under the conditions of high temperature and low pressure. To derive correctly the ideal gas law, we will learn some of the other very important laws for gases.

Browse more Topics under Thermal Properties Of Matter

- Calorimetry
- Change of State
- Heat Transfer

- Newton’s Law of Cooling
- Specific Heat Capacity
- Temperature and Heat
- Thermal Expansion

Boyle’s Law

Boyle’s Law states that ‘The absolute pressure exerted by a given mass of an ideal gas is inversely proportional to the volume it occupies if both the temperature and amount of gas remain unchanged’. In mathematical terms this law is given as:

P

∝

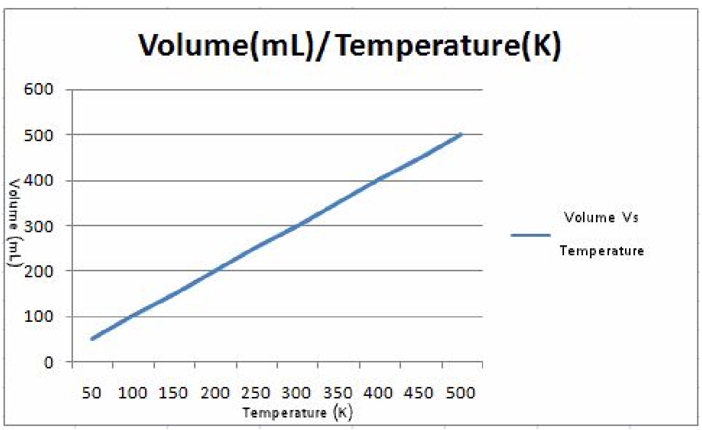
1/V or that PV = K

where P=Pressure of the gas; V=Volume of the gas; K=constant. It means that both the pressure and volume of a given mass of gas are inversely proportional to each other at a constant temperature. Furthermore, it also expresses that the product of pressure and volume for any gas is a constant and thus can be used to study the comparison of the gas under different conditions as:

P’V’ = P”V”

where both the products are for the same gas but under different pressures and volumes.

Charles’ Law



Charles’ law states that ‘ When the pressure of a sample of air is held constant, then the volume of the gas is directly proportional to its temperature‘, that is

V

∝

T

where V= Volume of a gas sample; T= Absolute temperature. Quite simply put, it says that Gases expand on heating and contract on cooling.

Avogadro’s Law

Avogadro’s law states that ‘Equal volumes of all gases at conditions of same temperature and pressure have the same number of molecules’, written as:

V

∝

n or V/n =K

where V=volume of gas; n=Number of moles (1 mole=6.022 x 10^{23} molecules). It implies that under similar conditions of pressure, volume and temperatures all gases will have an equal number of molecules, independent of the weight and density of the gas.

Ideal Gas Equation

If we combine the results of all the above gas laws we get an equation that holds true for an ideal gas. The most common form of this equation is since PV= K and V/T =k then

PV/T = constant

Thus, the Ideal Gas Equation is given as

PV = nRT

where P= pressure of the gas; V=volume of the gas; n= Number of Moles; T=Absolute temperature; R=Ideal Gas constant also known as Boltzmann Constant = 0.082057 L atm K^{-1} mol^{-1}.

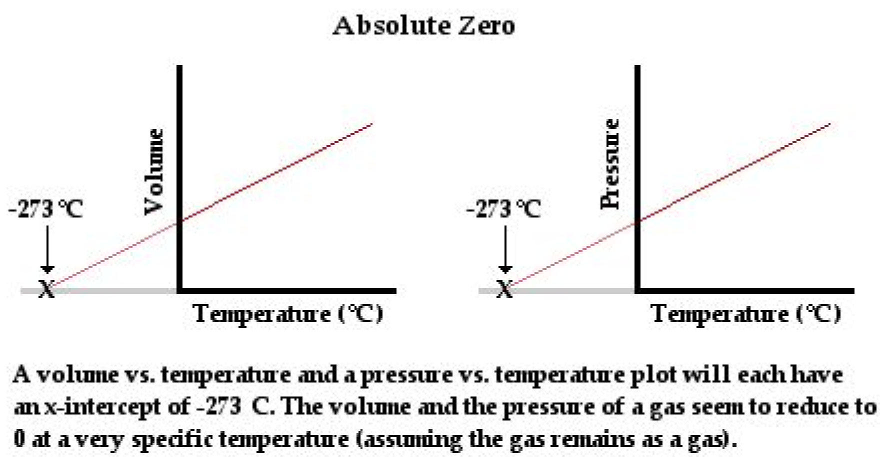
Using this equation, the study of any gas is possible under assumptions of STP conditions and subjecting the gas to reasonable restrictions to make it behave similarly to an Ideal gas.

What is an STP condition?

STP is short for 'Standard Temperature and Pressure'. STP condition is defined (as per the International Standard Metric Conditions) as the surrounding absolute temperature of 288.15 Kelvin (15° Celcius) and a pressure of 1 atmosphere i.e. 1 bar or 101.325 Kpa.

What is Absolute Temperature?

Thermodynamic temperature, which is also known as 'Absolute Temperature' is a basic parameter for the study of thermal properties of matter.



[Source:physicsclassroom]

Using an ideal gas equation we can use gas for measuring temperature accurately. Again, as this law is universal in nature, all gases can be used to get the accurate temperature irrespective of their masses and other physical properties.

However, in actual use, it is observed that real gases often deviate from this law as compared to an ideal gas. But over a wide temperature base, all real gases more or less follow a linear path as can be seen in the case of gases taken above with pressure on the Y-axis and temperature on the X-axis.

Assuming that gases continue to be in a gaseous state at lower temperatures we can extrapolate the lowest minimum temperature for a gas. This lowest possible temperature is called Absolute Zero. The temperature is obtained at -273.15° Celcius on the Celcius scale.

It is also responsible for the creation of a new temperature scale called as 'Kelvin' scale where absolute zero is taken as 0 and so this scale is also called as Absolute temperature scale. It is represented as Kelvin. Thus,

T(Celcius) = T(Kelvin) + 273.15

This conversion helps to determine the absolute temperature of a gas under study. Thus, we have finally derived the Ideal Gas equation after studying all the concepts involved which make up the gas laws. Thorough knowledge of these concepts is paramount to ensure the proper understanding of properties of a gas being subjected to thermal study and thus its applications.

Solved Examples for You

Question: How many moles of 'He' are contained in a 6-litre canister at 101 KPa and 27 ° C. Take R= 8.314 J/mol K

Solution: Using the Ideal gas equation, n = PV/RT

Therefore, on substituting the values(T = 27 + 273 = 300) we get,

= 101 x 6/ 8.314 x 300 = 606/2494.2 = 0.2429 moles

Hence, 0.2429 moles of 'He' are contained in a 6-litre canister at 101 KPa and 27 ° C

Newton's Law of Cooling

Let's suppose you wish to cool down a beverage. Now, will the room temperature brought by you be sufficient to keep the beverage cool at the time of your party? Is there a way to know the time taken by the beverage to reach the temperature of the refrigerator? Yes, and that is known as the Newton's Law of Cooling. What is it? Let's find out more about Newton's Law of Cooling.

Newton's Law of Cooling

Named after the famous English Physicist, Sir Isaac Newton, Newton's Law of Cooling states that the rate of heat lost by a body is directly proportional to the temperature difference between the body and its surrounding areas. Given that such difference in temperature is small and the nature of the surface radiating heat remains constant. To put it in simpler terms, we may say that the hotter an object is, the quicker it cools down.

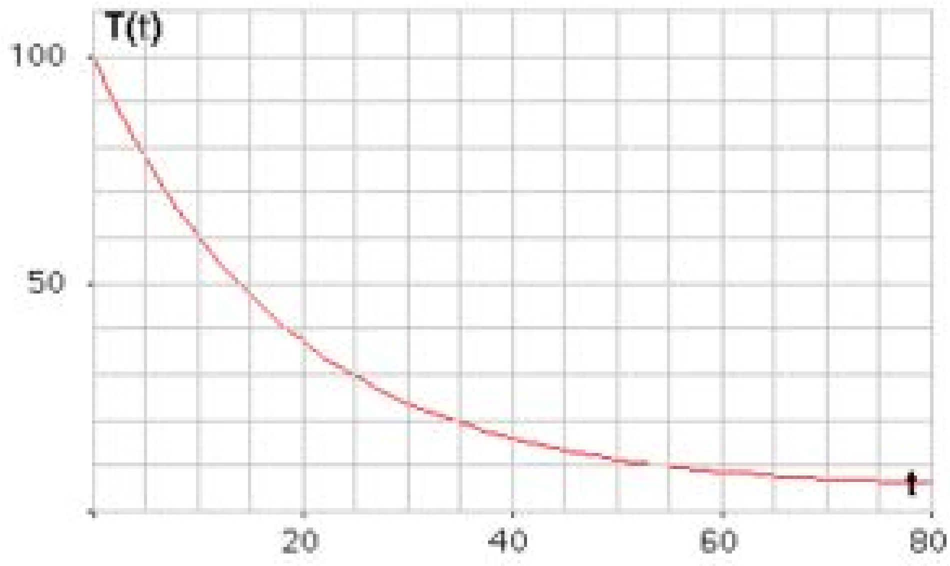
By temperature difference, we mean that any phenomenon which leads to the flow of energy into a system or flow of energy from any system into the surrounding area. In the former case, the object heats up, whereas in the latter, the object cools down. Newton's Law of Cooling leads to the often cited equation of exponential decline over time.

Browse more Topics under Thermal Properties Of Matter

- Calorimetry
- Change of State

- Heat Transfer
- Ideal Gas Equation and Absolute Temperature
- Specific Heat Capacity
- Temperature and Heat
- Thermal Expansion

This can be applied to several phenomena of science and engineering which includes discharge of a capacitor and the decay in radioactivity. The law is helpful in the study of heating water as it can help us calculate what speed the heater in the pipes cools off. To understand the application of this law in a practical sense would be that if you are going on a vacation and turn off the breaker, it will be able to tell you how fast the water heater will cool down.



Calculating the Rate of Heat Transfer

When we apply the definition of Newton's Law of Cooling to an equation, we can get a formula. So, as per the law, the rate of a body cooling is in direct proportion to the difference in body's temperature. Therefore,

- We take body temperature as T and the surrounding temperature as T_0
- The difference in temperature stays constant at 30^0 C. Calculating the thermal energy Q.

Note: the unit for thermal energy is joules. The formula derived from this equation is as follows:

$$\frac{dQ}{dt}\alpha(T - T_0)$$

Where,

- Mass of the body is represented by m
- Specific heat is represented by s
- And temperature is T
- Surrounding temperature is T_0

The formula for thermal energy will be as follows:

$$Q = msT$$

Now let us calculate the rate of cooling.

$$\frac{dQ}{dt} = ms\frac{dT}{dt}$$

Therefore, we get,

$$ms\frac{dT}{dt}\alpha\left(T - T_0\right)$$

Because we take mass and body heat as being constant, we can write the rate of change in temperature in the following manner:

$$\frac{dT}{dt}\alpha\left(T - T_0\right)$$

The equation gives above demonstrates that with the increase in time, the difference in the temperature of the body and its surroundings, decreases, which means, the rate of temperature will also decrease. Now let us apply this formula to a few problems so that we can understand its applications in a better way.

Question For You

Q. Let us suppose that a pot of soup has a temperature of 373.0 K, the temperature surrounding the soup is at 293.0 K. Let us supposed that the cooling at a constant temperature is k = 0.00150 1/s, at what temperature will the pot of soup be in another 20 minutes of time?

Sol: The time duration for the cooling of soup is given as 20 minutes. That is to say:

$$t = 20.0\ min \times \frac{60\ s}{1\ min}$$

Which brings about t = 1200 s. Now, in order to calculate the temperature of soup after the said time, we will apply the following formula:

$T(t) = Ts + (T0 – Ts)\ e^{(-kt)}$

$T(1200\ s) = 293.0\ K + (373.0\ K-293.0\ K)\ e^{(-(0.001500\ 1/s)(1200\ s))}$

$T(1200\ s) = 293.0\ K + (373.0\ K-293.0\ K)\ e^{(-1.800)}$

$T(1200\ s) = 293.0\ K + (373.0\ K-293.0\ K)(0.1653)$

$T(1200\ s) = 293.0\ K + (80.0\ K)(0.1653)$

T(1200 s) = 293.0 K + 13.224 K

T(1200 s) ≈ 306.224 K

Therefore, the temperature of soup after a duration of 20 minutes will amount to be 306.224 K.

Specific Heat Capacity

When you are out on the beach, have you noticed that the water is cold whereas the sand is hot! The sun is the same there, then why this difference in the temperature? You must have given it a thought! The temperature of a solid and liquid element rises when we supply heat to it. If we supplied the same amount of heat to two different kinds of solid then rise in temperature may be different in both the solids. So, depending upon the nature of the solid, the rise in temperature varies for different kind of solids. This phenomenon is known as Specific heat Capacity.

Definition

In other words specific heat of a solid or liquid is the amount of heat that raises the temperature of a unit mass of the solid through 1° C.

We symbolise it as C. In S.I unit, it is the amount of heat that raises the temperature of 1 kg of solid or liquid through 1K.

Its unit in S.I system is always given as J kg-1 K-1 and CGS as cal g-1 C-1. If the amount of heat, ΔQ, required to raise the temperature of mass M through ΔT, then the formula for specific heat is given by:

Browse more Topics under Thermal Properties Of Matter

- Calorimetry
- Change of State
- Heat Transfer
- Ideal Gas Equation and Absolute Temperature
- Newton's Law of Cooling
- Temperature and Heat
- Thermal Expansion

$$C = \Delta Q/m*\Delta T \text{ or } \Delta Q = m\ C\ \Delta T.$$

Molar Specific Heat

The Molar specific heat of a solid or liquid of a material is the heat that you provide to raise the temperature of one mole of solid or liquid through 1K or 1° C. We represent it as C. Its unit is J mol-1K-1. So, to raise the temperature of μ moles of solid through ΔT, you would need an amount of heat equal to $\Delta Q=\mu C \Delta T$.

The molar specific heat capacity of a substance is nothing but the amount of heat you need to provide to raise the temperature of one gram molecule of the substance through one degree centigrade. It is denoted by C. Specific heat of water is taken to be 1. This is because of the reason that we defined unit of heat (calorie) by making use of water.

Specific Heat at Constant Pressure or Volume

- The volume of solid remains constant when heated through a small range of temperature. This is known as specific heat at a constant volume. It is denoted as C_V.
- The pressure of solid remains constant when heated through a small range of temperature. This is known as specific heat at constant pressure which can be denoted as C_P.

The behavior of gas when heat is supplied, the pressure and volume change in temperature and the amount of heat required to raise the temperature for 1gm of gas through 1°C depends on the way gas is heated. You can use several sets of values of P and V heat the gas.

Therefore, specific heat possesses infinite values. The specific heat of the gas is not constant if you do not supply a constant amount of heat. So, you must have specific heat at a constant volume or pressure. For an ideal gas,

$$C_P - C_V = nR$$

where C_P is heat capacity at constant pressure, C_V is heat capacity at constant volume, n is amount of substance, and R=8.3144598(48) J mol−1 K and is the molar gas constant.

Applications

- The utensils used for cooking use a material of low specific heat. You can heat their bottoms quickly. This is because they have aluminium or copper polished bottoms. The handle of these utensils is made of high specific heat material to sustain the heat and to save our hands.
- Insulators use materials of high specific heat. For example wood. House made of wood are more useful in High temperature or Low-temperature area.
- Due to a high specific heat of water, in swimming pool, water used to be cool as compared to the temperature outside.

Question For You

Q. Give the definition of molar specific heat.

Ans: For a solid or liquid it is the heat that us required to increase the temperature of one mole of Solid or Liquid through 1K or 1° C.

Temperature and Heat

Often, we confuse heat with temperature. However, the two are very different concepts. Here, we'll not only discuss with you how the two are different from each other but will also help you understand the relation between the two.

Heat

We may define heat as a form of energy. This energy can lead to an increase or decrease in the internal energy of an object or body where the body remains static and no external work is done either on or by the body.

Browse more Topics under Thermal Properties Of Matter

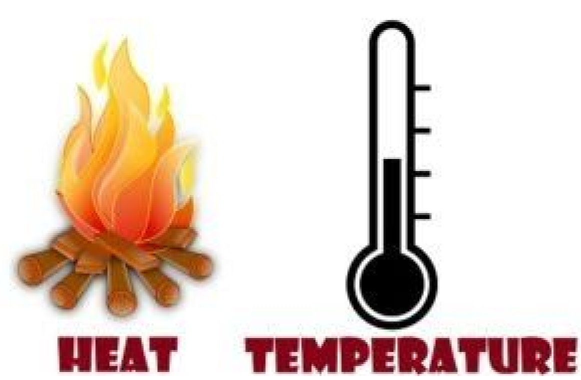
- Calorimetry
- Change of State
- Heat Transfer
- Ideal Gas Equation and Absolute Temperature
- Newton's Law of Cooling

- Specific Heat Capacity
- Thermal Expansion

Temperature

We have already understood that heat is the form of energy that leads to an increase or decrease in the internal energy of the body. This internal energy is also known as temperature. In other words, the temperature is a measurement by which we may measure the degree of hotness or coolness present in a body.

Temperature is measured in degrees. The measuring unit for temperature in Celsius and Fahrenheit. However, these measures are used in your daily life. For scientific measurement, we use the Kelvin scale.



(Source: keydifferences)

Let us now find out the equation for the three measurements.

- °F = (9/5 × °C) +32
- °C = (9/5)(°F- 32)
- K = C + 273°

What is a Clinical Thermometer? How is it Different from a Laboratory Thermometer?

A clinical thermometer is the one which we use to measure our body temperature. The thermometer which you normally find at your home or at a doctor's clinic is a clinical thermometer. The clinical thermometer is a long narrow tube made of glass. There is a silver looking bulb attached at the end of it. This bulb contains mercury, thereby making it look silver.

When this temperature is exposed to heat, the mercury in the bulb rises and depending upon the heat of the object points to the small numbers etched on the glass tube, indicating the temperature. One can also use the clinical thermometer to measure hot water. A laboratory thermometer looks pretty much like the clinical thermometer, which has a long narrow uniform glass tube with mercury in it, however, the temperature range of a clinical thermometer ranges from 35 degrees to 42 degrees Celsius.

On the other hand, the temperature range of a laboratory thermometer ranges from -10 degrees to 110 degrees Celsius. We use a clinical thermometer to measure the temperature of a human body, however, we cannot use laboratory thermometer to measure human body temperature.

While using a clinical thermometer we have the liberty to tilt is as per our convenience. But a laboratory thermometer has to be kept upright if we need to get a proper reading. The range of a laboratory thermometer is far wider than clinical one and therefore it has to be used with precision.

Let us learn more about Conductors and Insulators

What is Conduction?

Conduction is a process of transferring heat from one end of the object to another. Generally, this process transfers heat from the hotter end to the colder end.

Conduction is ideally only possible in the solid form. It is easier to conduct heat in the solid object because the atomic particles are tightly packed and in such a situation transference of heat from the hotter end of the object to the colder end can be done conveniently.

Conductors

We know that conduction is the transfer of heat from higher temperature to low temperature of an object. By that definition, a conductor is the means through which the process of conduction can take place. There are good conductors of heat and there are bad conductors of heat.

Those materials through which heat can easily pass are called good conductors of heat. Some example of good conductors of heat may be iron, aluminium or copper. You will notice that whenever you expose one end of these materials to the heat, the rest of the metal quickly heats up.

For example, you can try this experiment at home itself. Take a steel or aluminium spatula and expose it to the heat in your gas burner in the kitchen. You will notice that after a point of time the handle end of the spatula will start heating up and you will not be able to hold it for very long.

Insulators

Bad conductors of heat are those materials which do not permit heat to transfer from one end to another end very easily. For example, wood or plastic. It takes very long for heat to be transferred from one end of a wooden or plastic object to another. These bad conductors of heat are also known as insulators.

Let us take another example, repeating the same experiment as mentioned above, only this time take a wooden spatula. When you expose its one end to heat, you will notice that it takes very long for the other end to heat up. And even when it does, it is mild enough for you to keep holding the spatula with your bare hands. This proves that wood is a poor or bad conductor of heat.

This happens because the molecules in the wood are held strongly as a result of intermolecular force and thus these molecules fail to travel to the sour of heat, thus convection cannot happen in the woods.

Solved Examples for You

Question: The quantity of heat energy required to change the temperature of one gram of water by one degree Celsius is known as

A. 1 Joule
B. One Kilojoule
C. 1 Calorie
D. 1 Ampere

Solution: Option C – 1 Calorie. The amount of heat required to raise the temperature of one gram of water through 1° (from 14.5°C to 15.5°C), is called one calorie.

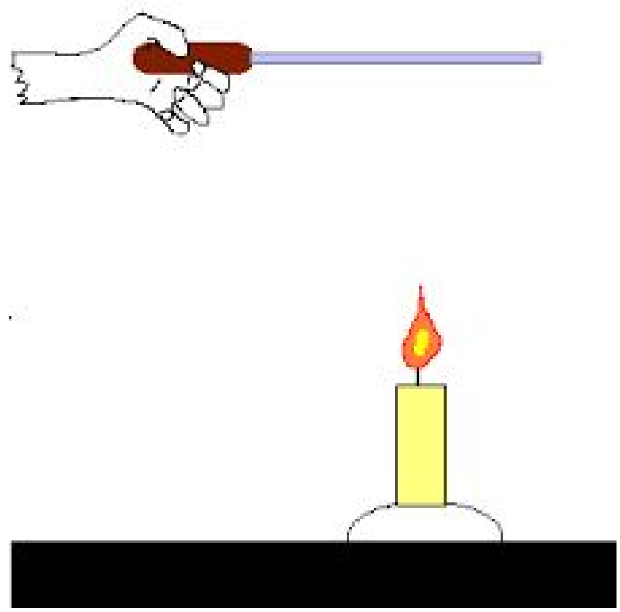
Thermal Expansion

Have you ever noticed that small gap in the railway tracks? Why do you think they are there? Or, have you ever noticed your mom trying to open up a jammed bottle, by heating up near its neck? What is this magic all about? Let's find out more about the process of thermal expansion here.

Thermal Expansion

If the temperature increases, then the volume of the material also increases. Generally, this is known as thermal expansion. We can express it in this way that it is the fractional change in length or volume per unit change in temperature. In case of expansion of a solid, normally linear expansion coefficient is usually employed.

In case of thermal expansion of solid, it is described in terms of change in length, height, and thickness. For liquid and gas, the volume expansion coefficient is more useful. Generally, if the material is a fluid then we can describe it in terms of change in volume.



Among the atoms and molecules, the bonding forces vary from material to material. Characteristics of elements and compounds are known as expansion coefficient. If a crystalline solid has the same structural configuration throughout, (isometric) then in all dimensions of crystal the expansion will be uniform.

If the crystal is not isometric then expansion coefficient is also different for different crystallographic directions and as the temperature will change then the crystal will also change the shape. Softer materials have a higher coefficient of expansion (CTE) but harder materials like tungsten have lower CTE.

Browse more Topics under Thermal Properties Of Matter

- Calorimetry
- Change of State
- Heat Transfer
- Ideal Gas Equation and Absolute Temperature
- Newton's Law of Cooling
- Specific Heat Capacity
- Temperature and Heat

Video on Thermal behavior of matter

Types of Expansion

- *Linear Expansion*: Linear expansion is defined as the increase in the length of the solid. Example: If we will consider one rod where the length of the rod is l, and we will increase the temperature of a rod by a small amount. So Linear Expansion is given by:

$$\frac{\Delta L}{L} = \alpha_L \Delta T$$

ΔL = change in length
L = original length
ΔT = change in temperature
α_L = linear coefficient of thermal expansion

- The Coefficient of linear expansion of the given solid is denoted as a. then for a unit is per degree Celsius) in the CGS and in the SI system it is per kelvin K^{-1}.
- *Volume Expansion*: Volume expansion is defined as the increase in the volume of the solid on heating. With a change in temperature Δt the change in volume of a solid is given by $\Delta v = V_y \Delta t$ where the coefficient of volume expansion is y.
- *Area or superficial Expansion*: Superficial expansion is defined as the increase in surface area of the solid on heating. If you consider at 0^0C area of a solid is A_0 then its area at t^0c is given by: $A_0(l+\beta t)$. Unit of β is $^0C^{-1}$ or K^{-1}. Where β is known as the coefficient of superficial expansion.

  $6\alpha = 3\beta = 2\gamma$

This equation shows the relationship between α is the linear expansion, β is the superficial expansion, is volume expansion. These three coefficients of expansion for a given solid are not constant because these values totally depend on the temperature. Examples of thermal expansion in our daily life are thermometers, riveting, on wooden wheels fixing metal tires etc.

Solved Example For You

Q. In one continuous piece from a roll of a sheet of aluminum modern eavestroughs are constructed. For a 30-meter-long what is the change in length? Where $\alpha=23\times10^{-6}C^{-1}$ for temperature range $\Delta T=100F$.

Ans: $\Delta L= L_0\ \alpha\ \Delta T$

$= (30m)\ (23\times 10^{-6})(500/9) = 3.8$ cm