II - Heat

Basic concept of quantity of heat. Definition and measurement of above concept of temperature thermometry, thermostat, thermocouple relevant to clinical laboratory, thermal capacity specific heat capacity, calorimetric techniques - calorific values of food and fuel- kinetic theory of gases - assumptions. Applications laws of thermodynamics -water bath- parts, care and usage. Incubator - parts, preventive maintenance and use of refrigerators techniques. Types of refrigerators - cooling; cycle production of low temperature vapour absorption change of stage, latent heat; cooling by evaporation.

Heat is a form of an energy. Heat is usually transferred from hot body to cold body when they are in contact. Then the transfer stabilizes at equal temperatures.

Unit: Joule

Calorie: one calorie is the amount of heat required to raise the temperature of water through one degree celsius

There are three modes of heat transfer:

Conduction

It is a type of process in which the heat is transfer from one point to another point without actual movement of the particles

Conduction

It is a process in which the heat is transfer from one point to another with actual movement of the particles.

Radiation

It is a process in which the heat is transferred from one point to another without any material medium

Properties of heat radiation

i. Similar to light, They are electromagnetic waves with longer wavelength
ii. They travel with a straight line with speed of light
iii. They get diffused when they fall on rough surface
iv. They travel through vaccum
v. They do not affect medium when they pass through it

Temperature

Temperature and kinetic energy are closely related. Temperature is the measurement of heat. Heat is the result of molecules colliding with one another. The temperature of a gas, with most of the internal energy spend keeping molecules in motion, is directly proportional to its kinetic energy. In contrast, the temperatures of solids and liquids represent only part of their total internal energy.

Absolute Zero

It is the temperature at which there is no kinetic energy because the molecule cease to vibrate to produce energy and the object has no heat to measure at that temperature. This is practically impossible to achieve because of third law of thermodynamics

Temperature scales

Multiple scales can be used to measure temperature. The Fahrenheit and Celsius scales are based on the properties of the water (Freezing and Melting points). A third scale, the kelvin scale, is based on molecular motion.

Centigrade scale

It is a scale which is used to measure the temperature difference between the freezing and melting points of water between 0 to 100˚C. The interval between two limits is divided by 100˚

Kelvin scale

It is a scale which is used to measure the temperature at a zero point equal to absolute zero(0 K). The Kelvin scale has triple - point definition of water (Freezing, Melting and Boiling points).

In Celsius unit, kinetic molecular activity stops at approximately -273˚C and 0˚C = 273 K. Therefore to convert Celsius to kelvin, simply add 273.

Fahrenheit scale

It is a scale which is used to measure the temperature difference between freezing and boiling point of water between 32˚F and 212˚F with the interval between two limits is divided by 180 scales. Our normal body temperature is 98.6˚F

Relationship between Celsius and Fahrenheit scales: $C = \frac{5}{9}(F-32)$

Thermometry

Thermometry is the process of measuring temperature. Nowadays, there are many different types of thermometers, for example glass in tube, thermistor, thermocouple, radiation thermometer etc. are used

Liquid thermometer is used to measure the measure the change in volume of liquid with change in temperature. Gas thermometer is used to measure the change in pressure of volume with change in temperature. Resistance thermometer is used to measure the change in resistance with change in temperature.

Clinical Thermometer

Mercury thermometer

- A pure glass capillary tube having bulb at one end
- Bulb is filled with pure and dry mercury
- Air is completely exhausted from the tube
- Open end is scaled by placing bulb in a bath whose temperature is higher than maximum temperature of mercury

Measurement process

- Thermometer is kept aside for several days before it is graduated
- The lower point is fixed by keeping the thermometer in melting ice and the mercury level is masked on glass capillary tube
- The upper point is fixed by placing hypsometer containing water. The bulb should be kept above the water level. When the water is boiled, the mercury is expanded and raises the level. Now the maximum level of mercury is fixed.
- Thermometer is now graduated by the dividing equally between upper and lower fixed points.

Features

- Low specific heat
- It is a good conductor
- Easily seen on fine capillary tube
- It does not wet the wall of the glass tube
- Uniform coefficient of expansion
- Remains as liquid over a large range of temperature
- The specific gravity is high

Advantages

- Fahrenheit scale
- Stem of thermometer is partially flat and parallel where flat surface helps in preventing the rolling of thermometer while curved surface is to magnify the scale reading.
- The ranges varies between 94 - 110˚F
- White coating at the capillary tube behind the mercury helps in visibility of thermometer reading.
- Bulb in thermometer is long. As a result the thermometer spreads over long distance. Hence it quickly absorbs heat and show the body temperature

Rectal thermometer is shorter, thicker walled bulb which is used for long time to record temperature.

Thermostat

A device that maintains a system at a constant temperature. It often consists of a bimetallic strip that bends as it expands and contracts with temperature, thus breaking and making contact with an electrical power supply. It is made up of semiconductor which exhibits reduction in electrical resistance with increase in temperature. Therefore, by measuring electrical resistance temperature can be measured.

Thermocouple

It is based on seeback effect. When two metal conductors are joined together to form a circuit, a potential difference is developed which is equal to the difference in temperature of two junctions. To measure temperature, one junction has to keep at constant temperature, by measuring the potential difference at the other junction, the temperature can be measured.

Thermal capacity

It is the quantity of heat required to raise the temperature of whole substance through one kelvin

Unit : J K^{-1}

Specific heat

When a body is heated, its temperature rises. The rise in temperature is not uniform for two bodies of equal mass. The rise in temperature depends on the quantity of heat given to the body and mature of the material. Let Q be the quantity of heat given by the body, θ be the rise in temperature and m its mass, then

$Q = m S \theta$

Where S is the specific heat which the quantity of heat required to raise the temperature of one gram of substance through one degree kelvin. It is not constant for a given substance, it differs at different temperatures. Unit: J $Kg^{-1}K^{-1}$

Calorimetric techniques

Calorimetry is the process of measuring the amount of heat released or absorbed during a chemical reaction. By knowing the change in heat, it can be determined whether or not a reaction is exothermic (releases heat) or endothermic (absorbs heat). Calorimetry also plays a large part of everyday life, controlling the metabolic rates in humans and consequently maintaining such functions like body temperature.

Constant pressure calorimetry

Constant pressure calorimetry is used to measure the heat of a reaction. In order to measure the heat of a reaction, the reaction must be isolated so that no heat is lost to the environment. This is achieved by use of a calorimeter, which insulates the reaction to better contain heat.

Constant volume calorimetry

Constant volume calorimetry, is used to measure the heat of a reaction while holding volume constant and resisting large amounts of pressure.

Differential scanning calorimetry

Differential scanning calorimetry is a specific type of calorimetry including both a sample substance and a reference substance, residing in separate chambers. While the reference chamber contains only a solvent, the sample chamber contains an equal amount of the same solvent in addition to the substance of interest, of which the ΔH is being determined. The ΔH due to the solvent is constant in both chambers, so any difference can be attributed to the presence of the substance of interest.

Calorific values of food and fuel

Calorific value is the amount of heat energy present in food or fuel and which is determined by the complete combustion of specified quantity at constant pressure and in normal conditions. It is also called calorific power. The unit of calorific value is kilojoule per kilogram i.e. KJ/Kg.

Water vapour is generated in the combustion process and the heat should be recovered by using certain techniques. If the heat contained in the water vapour could be recovered then it has high calorific value. If heat contained in the water vapour could not be recovered when it has low calorific value.

The efficiency of fuel or food mainly depends on the calorific value. If the value is high, its efficiency will also be high. If the value is low, its efficiency would also decrease. Calorific value is directly proportional to its efficiency.

The calorific value of food indicates the total amount of energy, a human body could generate during its metabolism which is expressed in Kilojoules per 100 grams or 100 ml. The calorific value of food is generally expressed in kilocalories i.e. kcal.

Category of food	**Quantity(Grams)**	**Calorific value (Approximately)**	
		Kilojoules(KJ)	**Kilocalories(Kcal)**
Dietary fibre	1	8	2
Polyhydric Alcohols	1	10	2.4
Alcohols	1	29	7
Carbohydrates	1	17	4
Protein	1	17	4
Fats	1	37	9

Kinetic theory of gases - Assumptions

To explain various properties of gases, Celsius, Boltzmann and Maxwell propose kinetic theory of gases whose postulates are as follows:

- The gases are made up of large number of tiny particles called molecules
- All the molecules of a given gas are identical in all respects like, mass, volume, etc.,
- A molecule of a given gas is perfectly rigid and as coloured as an elastic sphere
- The molecules moves along a straight line with different velocities in random direction
- While in motion, the molecules of gas continuously collide with each other and also with the walls of the container
- The distance covered by the molecule between any two successive collision with other gas molecules is called a mean free path

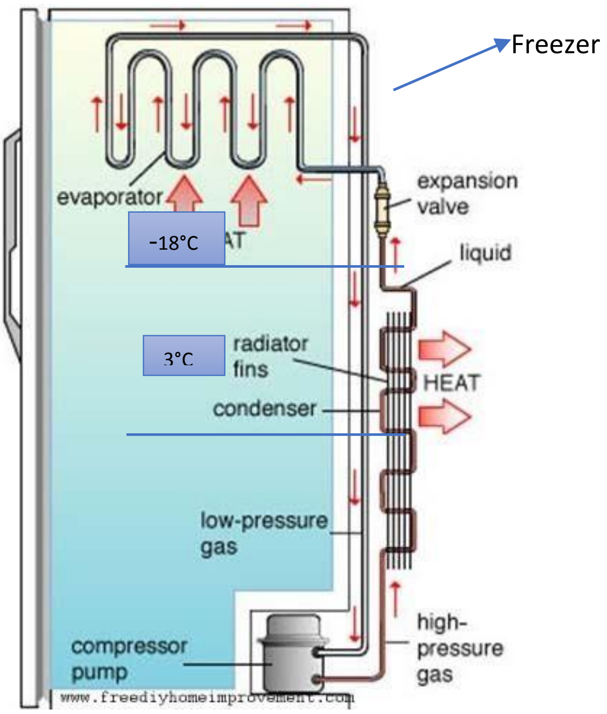
Applications of laws of thermodynamics

First law : Heat absorbed by a system (δQ) = Increase in internal energy (δU) + Amount of external workdone (δW). It is used to find the specific heat of a body

Second law: Heat will flow from cold body to hotter body when an external work is done on it

Applications:

Generally heat cannot flow from a cold body to hot body. But this is possible to do so, if some external work (or) pressure is done on the working substance. This concept is used in refrigerators.



Refrigerator

It is an equipment used to reduce and maintain the below atmospheric temperature and this obtained by removing the heat from the space continuously.

Refrigerant

It is a fluid which absorbs the heat from the body and rejects the heat at high temperature. Example: Ammonia, carbon di oxide, Freon, methyl chloride, chloro fluoro carbon (CFC)

Capacity of refrigerator (or) Refrigeration effect

It is the amount of heat extracted from the cold body per unit mass per second. (or) the rate at which the refrigeration produced is called the capacity for the refrigerator. It is expressed in tonne of refrigeration.

A tonne fo refrigeration is defined as the amount of refrigeration effect produced by uniform melting of one tonne of ice at 0°C to water in 24 hours.

1 Tonne refrigeration = 210 KJ/min (or) 3.5kJ/sec.

Principle

According to clausius, second law of thermodynamics states that, "*without doing external work it is impossible to transfer heat from a cold body to cold body*"

Here the ammonia takes heat from the refrigerator and due to external work done on ammonia, it gives heat to atmospheric air and keep the refrigerator continuously cool.

Design

It consists of two coils

(1) Evaporator coil to convert liquid ammonia to vapour and
(2) Condenser coil to convert vapour to liquid ammonia as shown in figure.

The compressor in the refrigerator is used to compress the ammonia vapour using a piston to a very high pressure and it helps in doing the external work on the ammonia. The whole setup is kept in well air circulation area for better performance.

Working

(1) In domestic refrigerator, liquid ammonia is used as the working substance for cooling the refrigerator
(2) Here, liquid ammonia at low pressure is passed through the evaporator coils, wherein it expands and absorbs the heat from the refrigerator.
(3) This liquid ammonia takes up the heat from the refrigerator and is converted into low pressure vapour.
(4) Now the compressor is sued to compress the ammonia vapour externally using a piston, to a very high pressure
(5) This ammonia at high pressure is allowed to pass through the condenser coils.
(6) While passing, the ammonia vapour gives heat to the atmospheric air at room temperature and becomes liquid ammonia again due to cooling.
(7) This cool liquid ammonia in turn act as primary refrigerant and keeps the refrigerator cool
(8) This cycle of process continues and makes the refrigerator to be in cool condition always.
(9) In modern days, chlorofluoro carbon (CFC) is used as refrigerant for effective cooling

Applications

(1) It is sued to preserve foods for a long time.
(2) It is used in refineries for removing wax

Advantages

(1) Protects foods from microbes, insects and rodents
(2) Store food for long time

Disadvantages

(1) It consumes large amount of electricity
(2) Harmful pollutant gas like CFC causes global warming

Preserving food for long duration is not good for health

Types

Top Freezer Refrigerator, Side-by-Side Refrigerator, Bottom Freezer Refrigerator. French Door Refrigerator, Counter-Depth Refrigerator, Mini Fridge.

WATER BATH

It is a device that maintains the water at constant temperature. It allows the heating of small amounts of fluids over a period of time without changing the concentration of constituents by evaporation. It is also used when several tubes are to be handled while maintaining the temperature of the contents, e.g: in coagulation tests.

Water bath is an instrument used for maintaining a uniform temperature throughout the fluid contained in a glass container by keeping it in preheated water. It also prevents excessive evaporation of the fluid being heated.

Components

It is made up of insulating metal, usually stainless steel or of heat the water contained in the trough. A propeller or stirrer to circulate the water in the trough in order to maintain a uniform temperature throughout the trough. A thermometer to check the temperature. This may be in-built or placed separately in the trough. A thermostat to maintain the temperature at a constant level.

Water bath controls

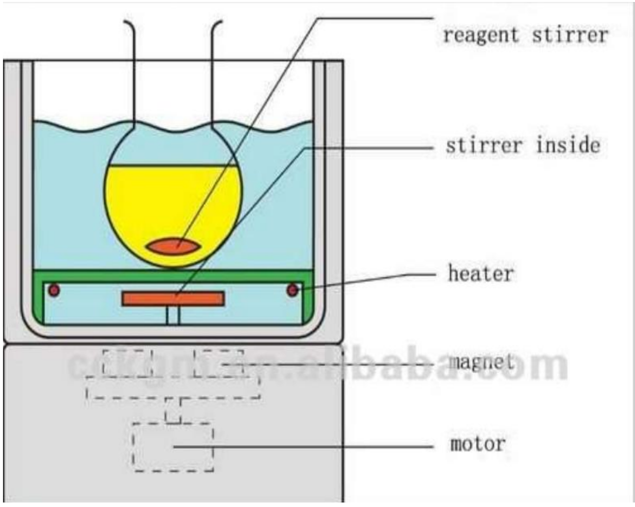
All water baths have a control to set temperature. This control can be digital or a dial. Often there is an indicator light associated with this control. When the light is on the water bath is heating. When the water bath reaches the set temperature, it will cycle on and off to maintain constant temperature.

Safety control

Most water baths have a second control called safety. This control is set just above the temperature control. Often an indicator light is associated with the safety control. If the water bath reaches the temperature that the safety control is set at, the light will go on. It will be impossible for the water bath to heat higher than safety setting even when the temperature setting is higher.

Shaking control

Shaking water baths have additional controls for shaking. The shaking mechanism can be turned on or off. The speed of shaking can also be set.



Operating procedure

Fill it clean (preferably distilled) water to a desired level and then switch it on. Set the thermometer to desired temperature and allow the water to warm to that temperature. Check the temperature from the thermometer.

Precautions and maintenance

Clean from inside and change the water daily. This will prevent encrustation of stirrer, heat probe and thermostat with salts contained in raw water. It will also prevent the growth of fungi and algae. Keep the lid closed when not in use to prevent evaporation of water. Periodically check and counter check the water temperature with internal as well as with an external thermometer. The thermometer should be placed in such a way that it is away from the heating element and the walls.

INCUBATOR

A heater and humidified apparatus for a new-born, often premature child. The use of incubators make it possible to provide the required environmental heat to maintain each infant's body temperature. (35.5 – 36.5). Infant's < 2000g for maintaining a constant environmental temperature. Sick infant's requiring close monitor ex.RDS. For isolation ex: whooping cough. For convenient and better management. Pre heat the incubator. Fill the water chamber with 2,200cc of sterile distilled water so that humidity can be increased if necessary. Se the pre heated incubator to the desire temperature and or as prescribed by the attending physician it can be regulated to meet the needs of the individual infant. Undressed the infant except for a diaper then place infant in incubator through opened access panel. Undressed the infant so that the flow of air will cantract the body surface. Do not use mercury thermometer in incubator. If the thermometer is accidentally broken inside the incubator, the neonate can be poisoned by the mercury. Minimal opening of incubator portholes. Infant servo temperatures are recorded hourly during the initial critical care stage, and compared with the patient's for hourly per axilla / per rectum record. Coordinate observations with feeding times unless otherwise indicated by the infant's condition. Any readings above 37'C and swinging incubator temperatures (indication of unstable temperature control) should be reported.