HEAT

LEARNING OBJECTIVES

* Heat and temperature.
* Thermometric scales.
* Heat capacity, water equivalent and specific heat.
* Change of state.
* Latent heat.
* Principle of Calorimetry.

Real time Applications:

* In medical field thermometers are used by the doctors to know the temperature of a patient.
* In industries with the help of heat energy many metals are going to convert into thin sheets and wires.
* In mechanics heat plays a wide role in running a motar vehicle.
* In factories the temperature of a resultant mixture can be found by using calorimetry principles.
* Calorimetry is used to determine the calorie content of a food.
* In chemical laboratories heat change is a fundamental to understand chemical reactivity and physical property of a given material.

Important Formulae:

1. $\frac{C-0}{100} = \frac{F-32}{180} = \frac{R-0}{80} = \frac{K-273}{100}$
2. $Q = ms$
3. $Q = m.C.\Delta t$
4. $Q = mL$
5. $\underset{(solid)}{Ice} \underset{cool}{\overset{heat}{\rightleftharpoons}} Water \underset{cool}{\overset{heat}{\rightleftharpoons}} \underset{(gas)}{Steam}(water\ vapours)$
6. *Principle of calorimetry:*
   Heat energy given out by hot body = Heat energy absorbed by cold body.

Heat and Temperature:

1. Heat is a form of energy which causes in us the sensation of hotness (or) coldness.
2. Temperature is the degree of hotness (or) coldness of an object.
3. Following points sum up the flow of heat energy from one body to another body.

i) Heat energy always flows from a body at higher temperature to a body at lower temperature till equilibrium is reached.

ii) At equilibrium temperature, the heat energy does not flow.

iii) The rate at which the heat energy flows from a hot body to a cold body depends upon the difference in temperatures of both the bodies.

iv) The amount of heat energy flowing into the cold body is always equal to the amount of

heat energy supplied by the hot body.

i.e Heat energy lost (given out) = Heat energy gained OR absorbed.

Effects of heat energy :

i) Heat energy brings about change in temperature.
ii) Heat energy brings about change in dimensions.
iii) Heat energy brings about change in the states of matter.
iv) Heat energy bring about chemical changes in matter.

Units of heat :-

system	Unit	Symbol
C.G.S	calorie	Cal
S.I	joule	J
1 Calorie = 4.18 J	Kilo calorie = 4180	J

Units of temperature :

Generally temperature is measured in degree Celsius (^{0}C).
In S.I system temperature is measured in kelvin (K).

Thermometer:

* It is a device used for measuring the temperature of different objects.
* First thermometer was invented by Galileo in 1593 AD. In this thermometer air was used as the thermometric substance,as the air rapidly expand on heating and
contract on cooling.

1. Clinical Thermometer :

1) It is used for measuring the temperature of the human body.
2) It is graduated in between 35 - 42^{0}C (or) 95 - 108F
3) In this, the bend (constriction) in the bore does not allow the mercury to fall back in the bulb after its use, unless the thermometer is vigorously shaken.
4) The normal temperature of a human body is 98.4^{0}F or 36.9^{0}C.

2. Maximum and minimum Thermometers :

For recording the maximum and minimum temperatures reached on any particular day, maximum and minimum thermometers are used. They are:

i) Rutherford's maximum Thermometer.
ii) Rutherford's minimum Thermometer.
iii)Six's maximum and minimum Thermometer.

The other Thermometers are

i) Laboratory thermometer ii) Alcohol Thermometers,etc.

Reasons for using mercury in Thermometers:

1) Mercury needs very little heat to expand. Thus, it can easily record the temperature of a body without changing the temperature of the body.
2) The temperature at which mercury boils is 357^{0}C. Thus, it can be used to record temperatures as high as 357^{0}C.
3) The temperature at which mercury changes into solid state is - 39^{0}C.
4) Mercury does not stick to the sides of the capillary tube. Thus, it helps in recording accurate temperature.
5) Mercury is opaque and shining. Thus, it can be easily seen as a fine thread in the capillary tube.

Reasons for using Alcohol in Thermometers:-

1) Freezing point of alcohol is less than - 100^0C.
2) Alcohol expands more than mercury for the same rise (or) fall in temperature. Thus, alcohol thermometers can measure more accurately than mercury.
3) Alcohol can be brightly coloured and hence, can easily be seen in the glass capillary tube.

Standard points (or) fixed points:- The fixed temperatures marked on the stem of a thermometer by the common consent of scientists.

Lower standard point (or) lower fixed point : The melting point of pure ice at a pressure of 76 cm of mercury.

Upper standard point (or) upper fixed point : The boiling point of pure water at a pressure of 76 cm of mercury.

Thermometric Scales :

1) Celsius (or) Centigrade Thermometer:

* This scale was introduced by Celsius.
* On this scale 0^0C represents the melting point of ice and 100^0C is the steampoint.
* This scale is divided into 100 equal parts.

2) Fahrenheit Scale :

* This Scale was introduced by Fahrenheit.
* On this Scale 32^0F represents the melting point of ice and 212^0F the steam point.
* The length in between the standard points is divided to 180 equal parts. Each division on this scale is called 1^0F.

3) Reaumur scale:

* This Scale was introduced by Reaumur.
* On this Scale 0^0R represents the melting point of ice and 80^0R the steam point.
* The length in between the standard points is divided to 80 equal parts.Each division on this scale is called 1^0R.

4) Kelvin scale:

Temperature on kelvin scale= Temperature in ^{0}C+273.

Relation between different temperature scales: $\frac{C-0}{100}=\frac{F-32}{180}=\frac{R-0}{80}=\frac{K-273}{100}$

Note : The relation between centigrade scale and Fahrenheit scale can also be written as

$$F=\frac{9}{5}C+32\ .\left(\because \frac{C}{100}=\frac{F-32}{180}\Rightarrow\frac{C}{5}=\frac{F-32}{9}\Rightarrow\frac{9C}{5}=F-32\Rightarrow F=\frac{9C}{5}+32\right)$$

EXAMPLES

Ex 1 : Convert -10^0C into Fahrenheit scale.

Sol: C= -10^0C

$$F=\frac{9}{5}C+32=\frac{9}{5}(-10)+32=14^0F$$

Ex 2: Convert the normal temperature of a human body 98.4^0F into Celsius scale.

Sol: $F=98.4^0F$

$$C=\frac{5}{9}(F-32)=\frac{5}{9}(98.4-32)=\frac{5}{9}(66.4)=36.9^0C$$

Ex 3 : Show that -40^o measure the same temperature on Celsius and Fahrenheit scales.

Sol: $Let\, C = F = x, Substituting\ \ in$

$$\frac{C-0}{100}=\frac{F-32}{180}\Rightarrow\frac{x-0}{100}=\frac{x-32}{180}\Rightarrow\frac{x}{5}=\frac{x-32}{9};9x=5x-160$$

$$\Rightarrow 4x=-160\Rightarrow x=-40^o$$

Ex 4: Express 200K on Fahrenheit scale.

Sol: On any scale of temperature, $\frac{\text{Re}\,ading-LFP}{UFP-LFP}=a\,cons\tan t$

On the Kelvin and Fahrenheit scales,

$$\frac{K-273.15}{373.15-273.15}=\frac{F-32}{212-32}\Rightarrow\frac{K-273.15}{100}=\frac{F-32}{180}$$

Where K and F are the readings on kelvin and Fahrenheit scales respectively. In this problem, K=200K

$$\frac{200-273.15}{100}=\frac{F-32}{180}\Rightarrow 200-273.15=\frac{100}{180}(F-32)$$

$$-73.15=\frac{5}{9}F-\frac{160}{9}\Rightarrow F=\frac{9}{5}\left(-73.15+\frac{160}{9}\right)=-99.68K$$

Ex 5: The triple points of neon and carbon dioxide are 24.57K and 216.55 K respectively. Express these temperatures on the Celsius and Fahrenheit scales.

Sol: Triple point of neon:24.57K; Triple point of carbon dioxide =216.55K.

On Celsius scale:C=T-273.15

Triple point on neon =24.57-273.15=-248.58^{0}C.

Triple point of carbon dioxide=216.55-273.15=-56.6^{0}C.

On Fahrenheit scale :F=$\frac{9}{5}C+32$

Triple point of neon= $=\frac{9}{5}-248.58+32=-415.26^0F$

Triple point of carbon dioxide= $=\frac{9}{5}(-56.6)+32=-69.88^0F$.

Ex 6: What is the temperature for which the readings on Kelvin and Farenheit scales are same?

Sol: On the Kelvin and Farenheit scales

$$\frac{K-273.15}{100}=\frac{F-32}{180}, Here, K=F$$

$$\frac{F-273.15}{100}=\frac{F-32}{180}\Rightarrow F-273.15=\frac{5}{9}F-\frac{160}{9}$$

$$\Rightarrow F=\frac{2298.35}{4}=574.59$$

Ex 7: A faulty thermometer has its fixed points marked as 5^0 and 95^0. The temperature of a body as measured by the faulty thermometer is 59^0. Find the correct temperature of the body on Celsius scale.

Sol : On any scale of temperature $\frac{\text{Reading} - LFP}{UFP - LFP} = a\,cons\tan t$.

Let the reading on the faulty thermometer be x and the corresponding reading on Celsius scale be C, By the above expression for the faulty thermometer and Celsius scale,

$$\frac{x - LFP}{UFP - LFP} = \frac{C - 0}{100 - 0} \Rightarrow \frac{x - 5}{95 - 5} = \frac{C}{100}$$

$$\Rightarrow C = \frac{100}{90}(x - 5) = \frac{10}{9}(59 - 5) = 60^{o}C\left(\because x = 59^{o}\right)$$

Ex 8: Express 0 K on Fahrenheit scale.

Sol: $\frac{K - 273.15}{100} = \frac{F - 32}{180}$

$$\Rightarrow \frac{0 - 273.15}{100} = \frac{F - 32}{180} \Rightarrow -273.15 = \frac{100(F - 32)}{180}$$

$$-273.15 = \frac{5}{9}(F - 32) \Rightarrow F - 32 = -491.67 \Rightarrow F = -459.67^{0}F$$

Ex 9: On reaumer scale of temperature the melting point of ice and the boiling point of water are taken as 0^0 R and 80^0 R respectively. The freezing point and boiling point of mercury on Celsius scale -39°C and 367°C respectively. Express these temperatures on reaumer scale.

Sol: i) $\frac{C}{100} = \frac{R}{80} \Rightarrow \frac{-39}{100} = \frac{R}{80} \Rightarrow -39 \times 8 = R \times 10$ = R = -31.2°C

ii) $\frac{367}{100} = \frac{R}{80} \Rightarrow$ R ×10 = 2936 ⇒ R = 2936/10 ⇒ R = 293.6°

Ex 10: A faulty thermometer has its fixed points marked as 3^0 and 102^0. The temperature of a body as measured by the faculty thermometer is 80^0. Find the correct temperature of the body on Celsius scale.

Sol: $\frac{\text{Reading} - L.F.P}{U.F.P - l.F.P} = a\ (cons\tan t)$

$$= \frac{x - L.F.P}{U.F.P - L.F.P} = \frac{C - O}{100} \Rightarrow \frac{x - 3}{102 - 3} = \frac{C}{100} \Rightarrow C = \frac{100}{99}(x - 3) \Rightarrow C = \frac{100}{99}(80 - 3)$$

$$\Rightarrow C = \frac{100}{99} \times 77 \Rightarrow C = 77.8^{0}C$$

Ex 11: At what temperature on the Fahrenheit scales will the reading be double of the reading on the Celsius scale?

Sol: $C = \frac{5}{9}(F - 32)$, let $C = x$ then F=2x

$$9C = 5F - 160 \Rightarrow X = 160^{0}C \Rightarrow F = 2x\ F = 2 \times 160^{0}F \Rightarrow \text{F= } 320^{0}F$$

Ex 12: An accurate Celsius thermometer and a Fahrenheit thermometer register 60^0 and 141^0 respectively when places in the same constant temperature enclosure. What is the error in the Fahrenheit thermometer?

Sol: $\frac{C}{100}=\frac{F-32}{180} \Rightarrow \frac{60}{100}=\frac{F-32}{180} \Rightarrow F-32=\frac{60\times180}{100} \Rightarrow F-32=108$

$\therefore F=140^0$ but given data F= 141^0F

$\therefore$ The error in $F^0=141-140=1^0F$

TEACHING TASK

I. Single correct option questions:

1. The temperature of liquid hydrogen is 20 K. What is the temperature on the Fahrenheit scale
   A) 495.4^0F B) - 423.4^0F C) -108.56^0F D) - 487.4^0F
2. At what temperature do the Centigrade and Fahrenheit scales give the same reading
   A) 100^0 B) 40^0 C) -40^0 D) 0^0
3. A thermometer which has upper and lower fixed points marked as 95^0C and 5^0C. It reads 59^0C. What is the correct reading on the centigrade scale
   A) 58 B) 59 C) 60 D) 61
4. A thromometer has wrong caliberation, it reads the melting point of ice as -10^0C.It reads 60^0C in the place of 50^0C. Then the temperature of the boiling point of water is
   A) 100 B) 110 C) 120 D) 130
5. The temperature of a body rises by 1K. How much is the corresponding rise in ^{0}C
   A) 1^0 B) 4^0 C) -4^0 D) 5^0
6. The reading on Fahrenheit scale at which its reading is 3 times to that of centigrade scale is..
   A) 100^0F B) 40^0F C) -40^0F D) 80^0 F
7. The temperature at which the reading on Celsius scale is only 1/10 th of Fahrenheit scale is..
   A) 10^0 B) 3^0 C) 9^0C D) 3.9^0C

III. More than one correct option questions

8. The relation between the Celsius and Fahrenheit temperature scales is

   a) $\frac{C-100}{212}=\frac{F-18}{32}$ b) $\frac{C}{100}=\frac{F-32}{180}$

   c) $\frac{C}{5}=\frac{F-32}{9}$ d) $\frac{C-32}{100}=\frac{F}{180}$

   A) a,b,c correct B) a,b correct C) a,b,d correct D)b,c correct
9. A temperature of $50^\circ C$ is equal to
   a) 122^0F b) 40^0 R c) 333 K d) 323 K
   A) a,b,c correct B) a,b correct C) a,b,d correct D) all correct
10. Choose the correct statement
    a) More sensitive celsius thermometers have 200 divisions between standard point and they are called as half 0^0 C thermometers.
    b) Farenheit scale is used for meteorological and clinical purposes

c) Kelvin scale of temperature also called as S.I scale of temperture
d) There cannot be any temperature below 0k
A) a,b,c B) a,b C) a,b,d D) all

Assertion - A and Reason - R:

A) Both A and R are true and R is the correct explanation for A.
B) Both A and R are true and R is not correct explanation of A.
C) A is true but R is false. D) A is false but R is true

11. A: A degree on Kelvin scale is 1/100 th part of the interval between the ice point and the steam point.
R: A degree on Reaumur scale is 1/80th part of the interval between the ice point and the steam point.
12. A: Normal temperature of human body is 98.6^0F
R: Doctors use laboratory thermometers to measure the temperature of a patient.

Match the following.

13.

a) Clincial	1) Temprature of insects
b) Six's max min	2) Temprature variation
c) Pyrometer	3) Temparature of sun
d) Thermocouple	4) Temprature of human body.

A) a-1,b-4,c-2,d-3 B) a-3,b-1,c-2,d-4
C) a-2,b-1,c-4,d-3 D) a-4,b-2,c-3,d-1

Comprehension type questions:-

14. $\frac{C}{5} = \frac{F-32}{9} = \frac{K-273}{5} = \frac{R}{4}$

i) Express 200 K in °C.
A) –273°C B) 100°C C) 212°C D) –73°C
ii) Express 37°C in Kelvin.
A)100 K B) 200 K C) 310 K D) 400 K
iii) Express 100° F in degree reaumur.
A) 37.8°R B) 40°R C) 80°R D) 30.2°R

Fill in the blanks:

15. The upper fixed point of Fahrenheit scale is .....
16. The best thermometric liquid to measure high temperatures is .....
17. SI unit of temperature is.....
18. The number divisions on centigrade scale are .....
19. If temparature increased in centrigrade scale by 10^0 the corrospondig increase in kelvin scale is .....

Key: 1) B, 2) C, 3) C, 4) D, 5) A, 6) D, 7) D, 8) D, 9) C, 10) D, 11) B, 12) C, 13) D, 14) i) D, ii) C, iii) D, 15) 212^0F, 16) mercury, 17)kelvin 18) 100, 19) 10

LEARNER'S TASK

BEGINNERS (Level - I)

I. Single correct option questions:

1. Choose the correct statement
   A) $1^0C < 1^0F$ B) $1^0F = 1^0C$ C) $1^0F < 1^0C$ D) $1^0C \geq 1^0F$
2. Temperature in Kothagudem on June 1st is 40^0C. Express it in kelvin
   A) 313K B) 40K C) 273K D) 231K
3. The measure of degree of hotness or coldness of a body is called
   A) heat energy B) Celsius C) kelvin D) temperature
4. The difference between lower fixed point and upper fixed point is divided into ..... parts on Celsius scale
   A) 100 B) 273 C) 180 D) 50
5. The range of clinical thermometer is
   A) $0 - 100^0C$ B) $32 - 212^0F$ C) $0 - 273^0C$ D) $35 - 42^0C$
6. The number of divisions between the lower fixed point and the upper fixed point on the kelvin scale are
   A) 100 B)273 C) 180 D) 212
7. The boiling point of water expressed on the Fahrenheit scale is
   A) 100^0F B) 212^0F C) 180^0F D) 273^0F
8. Melting point of ice represented on the Fahrenheit scale is
   A) 32^0F B) 0^0F C) 100^0F D) 212^0F
9. At low temperatures ..... type of thermometer is used
   A) mercury thermometer B) water thermometer
   C) alcohol thermometer D) thermometers cannot be used
10. A difference in temperature of 1^0C is same as a
    A) difference in temperature of 1K B) difference in temperature of 273K
    C) difference in temperature of 10K
    D) difference in temperature of 1^0F
11. A difference in temperature at 11^0C is same as
    A) difference in temperature 11K B) difference in temperature of 273K
    C) difference in temperature of 10K D) difference in temperature of 11^0F
12. On a Fahrenheit scale
    A) boiling point of water is 212^0F
    B) The temperature will be equal to that on the Celsius scale at -40^0C
    C) The difference between the upper fixed point and the lower fixed point is divided into 180 equal parts D) all the above
13. The lower fixed point on the Celsius scale
    A) melting point of ice B) boiling point of water
    C) melting point of mercury
    D) mean of melting point and boiling point of water
14. In the Celsius scale, the upper fixed point is
    A) melting point of ice B) boiling point of water
    C) boiling point of mercury D) mean of melting point and point of water

Key: 1) A, 2) A, 3) D, 4) A, 5) D, 6) A, 7) B, 8) A, 9) C, 10) A, 11) A, 12) D, 13) A, 14) B.

ACHIEVERS (Level - II)

I. More than one correct option questions

1. Choose the correct statements:
   a) S.I. unit of temperature is kelvin b) Temperature is a scalar quantity.
   c) S.I. unit of heat is joule(J). d) 1 cal = 4.2 J
   A) a,b,c B) a,b C) a,b,d D) all
2. Units(s) of heat energy is
   a) Joule b) Calorie c) Kelvin d) Celsius
   A) a,b,c correct B) a,b correct
   C) a,b,d correct D) all correct
3. Mercury is the commonly used thermometric liquid because
   a) it can be easily obtained in pure state
   b) it does not stick to glass tube thermometer
   c) It has a very high density
   d) It has very low freezing point and a very high boiling point
   A) a,b,c correct B) a,b correct
   C) a,b,d correct D) all correct
4. choose the correct option :
   a) Temperature is a scalar quantity b) Heat is a vector.
   c) The device for measuring the temperature of a substance is called a thermometer
   d) The device for measuring the heat of a substance is called a thermometer
   A) a,b,c B) a,b C) a,b,d D) a,c

II. Assertion - A and Reason - R:

A) Both A and R are true and R is the correct explanation for A.
B) Both A and R are true and R is not correct explanation of A.
C) A is true but R is false. D) A is false but R is true

5. A: Heat is a vector Quantity.
   R: Temperature is a scalar Quantity.
6. A: 1 J = 4.18 Cal.
   R: Heat energy always travel from hot body to cold body.
7. A: There are 100 divisions in a celsius thermometer.
   R: There are 80 divisions in a kelvin scale.

II. Match the following.

8.

Scale	LFP and UFP
a) centigrade	1) 32, 212
b) Fahrein heat	2) 0, 100
c) Reaumur	3) 0, 80
d) Kelvin	4) 273, 373

A) a-1,b-4,c-2,d-3 B) a-3,b-1,c-2,d-4 C) a-2,b-1,c-3,d-4 D) a-4,b-1,c-3,d-2

9.

Scale	no. of divisions
a) Celsius scale	1) 100
b) Fahrenheit scale	2) 180
c) Kelvin scale	3) 212
d) Reaumer scale	4) 80

A) a-1,b-4,c-2,d-3 B) a-1,b-2,c-3,d-4 C) a-2,b-1,c-4,d-3 D) a-4,b-1,c-3,d-2

IV. Comprehension type questions:-

10. For measuring temperature Celsius scale, Fahrenheit scale , Kelvin scale and Reaumur scale may be used.
    I) The scale on which ice point is taken as 0 and steam point is taken as 100 is
    A) Celsius scale B) Fahrenheit scale C) Kelvin scale D) Reaumur scale
    II) The scale on which ice point is taken as 32 and steam point is taken as 212.
    A) Celsius scale B) Fahrenheit scale C) Kelvin scale D) Reaumur scale
    III) The scale on which ice point is taken as 273 and steam point is taken as 373.
    A) Celsius scale B) Fahrenheit scale C) Kelvin scale D) Reaumur scale

Key: 1) D, 2) B, 3) D, 4) D, 5) D, 6) D, 7) C, 8) C, 9) B, 10) I) A, II) B, III) C.

Fill in the blanks:

1. If heat is the cause then temperature is its .....
2. Relation between centigrade scale and kelving scale is .....
3. 1^0 rise in kelvin scale is equl ..... rise in Fahrenheit scale
4. The temperature scale which doesnot have negative readings is .....
5. LFP of Fahrenheit scale is .....

Key: 1) effect, 2) K = C + 273, 3) 1.8^0, 4) kelvin, 5) 32^0F

EXPLORERS (Level - I)

Solve the following

1. The temperature at which the reading of Fahrenheit thermometer will be double that of a centigrade thermometer
2. Temperature of human body on Fahrenheit scale is 98.4^0. Corresponding reading on centigrade scale is...
3. A difference of temperature of 25^0C is equivalent in Fahrenheit to a difference of....
4. Temperature of iron block is 140^0F. Its temperature in Celsius scale is ...
5. A mountain climber finds that water boils at 80^0C. The temperature of boiling point of water in ^{0}F is...
6. The temperature of a freezing mixture is -18^0C. Its value in Fahrenheit scale is ...
7. Numerical values of the temperature measured in Centigrade and Fahrenheit scales are the same at..
8. Oxygen boils at -183^0C. This temperature approximately equals to in Fahrenheit scale is .....
9. A faulty thermometer has L.F.P. at 4^0C and U.F.P. at 94^0C. Temperature at which it shows correct reading is ..
10. A faulty thermometer has L.F.P. at 5^0C and U.F.P. at 95^0C. If the reading shown by that thermometer is 41^0, the correct reading if measured with correct centigrade thermometer is..

EXPLORERS (Level - I)

11. The reading on Fahrenheit scale at which its reading is 3 times to that on Reaumur scale is..
12. A scientist wants to develop a new scale for measuring Temperature. When his thermometer is put in melting ice, the reading is 20^0 and when put in steam, the reading is 120^0. The temperature on his thermometer for 98.6^0F is ...

13. Freezing point on a thermometer is marked as 20^0 and the boiling point as 150^0. A temperature of 60^0C on this thermometer will be read as ...
14. A thermometer has its fixed points marked as 5 and 95. What is the correct tempera ture in ^{0}C, when it reads 59 ^{0}C ?
15. The lower and the upper fixed points of a mercury thermometer were erroneously marked as 10^0C, and 90 ^{0}C, respectively. Calculate the correct temperature corre sponding to a temperature of 58 ^{0}C with this thermometer.
16. The temperature at which the reading of Fahrenheit thermometer is 2 times to that of centigrade thermometer is ...

Key: 1) 160^0C, 2) 36.9^0C , 3) 45^0F , 4) 60^0 C,5) 176^0 F, 6) -0.4^0F, 7) -40^0 , 8) -297^0F, 9) 40^0C, 10) 40^0C, 11) 128^0C, 12) 57^0, 13) 98^0, 14) 60 ^{0}C. 15) 60 ^{0}C, 16) 160 ^{0}C.

Heat capacity (or) Thermal capacity (C) :

The amount of heat energy required to raise the temperature of a given mass of a substance through 1^0C.

Heat capacity = heat required to rise the temperature of the body through 1°C

Mathematically, heat capacity = $\frac{\text{amount of heat}}{\text{Rise in temperature}} = \frac{Q}{\Delta t} \Rightarrow H = \frac{Q}{\Delta t}$.

Hence Thermal Capacity = mass × specific heat.

Units of heat capacity :

S.I. unit of heat capacity is $J\,K^{-1}$

CGS unit of heat capacity is $cal\,°C^{-1}$

WATER EQUIVALENT:

-Mass of water which has same thermal capacity as that of the substance is called water equivalent

i) It is numerically equal to heat capacity (ms)

ii) The S.I unit is kg

iii) The C.G.S unit is g

Factors on which heat absorbed/given out by a body depends :

i) directly proportional to the mass of the body.

ii) directly proportional to change in temperature of the body .

iii) depends upon the nature of body.

$Q = m.C.\Delta t$

Specific heat capacity or specific heat :

As $Q = m.C.\Delta t$. If m = 1 unit ; Δt = 1°C then Q = C, hence specific heat is the amount of heat required to raise the temperature of unit mass of the substance through 1°C or 1K. Mathematically,

$$\text{Specificheat} = \frac{\text{quantity of heat}}{\text{mass of the substance} \times \text{change in temperature}}$$

$$\Rightarrow C = \frac{Q}{m.\Delta t}$$

Note : 1.Of all known substances water has the highest specific heat capacity. It can absorb a lot of heat without its temperature going up very much. It also cools down slower than other substances, as it has to lose more heat to cool down.

2.The value of specific heat for a given substance is a constant quantity. However,

the specific heat capacity for different substances is different.

Units of specific heat :

S.I unit of specific heat = J kg^{-1} K^{-1}

CGS unit of specific heat is cal g^{-1} $°C^{-1}$

Since 1cal = 4.18 J therefore 1 cal g^{-1} $°C^{-1}$ = 4180 J kg^{-1} K^{-1}

Advantages of high specific heat capacity of water :

i) Formation of wind cycles and weather. A) Sea Breeze, B) Land Breeze.

ii) Use of water in hot water bottles.

iii) Use of water as coolant in car radiators.

iv) Use of water in the internal heating of buildings.

Solved Examples:

Ex 1: A lump of iron of mass 2kg is heated from 40^0C to 1000^0C.If the heat supplied is 192 k cal find its thermal capacity. Find also the specific heat of iron.

Sol: Heat supplied $\Delta Q = 192\,\text{k cal} = 192\times10^3\times4.2\text{J}; \text{mass } m = 2\,\text{kg};$ rise in temperature $\Delta t = 1000 - 40 = 960^0\text{C}$

Thermal caacity (H) = $\frac{Q}{\Delta t} = \frac{192\times10^3\times4.2J}{960}$

H = 840J/K.

Specific heat of lump of iron $= \frac{\Delta Q}{m\Delta t} = \frac{840}{2} = 420\,\text{J/kg K}$

Ex 2: Two spheres of radii in the ratio 1:2, have specific heats in the ratio 2:3, The densities are in the ratio 3:4. Find the ratio of their thermal capacities.

Sol: Thermal capacity of a body = ms

The ratio of thermal capcities

$$= \frac{m_1s_1}{m_2s_2} = \frac{v_1\rho_1s_1}{v_2\rho_2s_2} = \frac{\frac{4}{3}\pi r_1^3\rho_1s_1}{\frac{4}{3}\pi r_2^3\rho_2s_2} = \left(\frac{r_1}{r_2}\right)^3\left(\frac{\rho_1}{\rho_2}\right)\left(\frac{s_1}{s_2}\right)$$

Here, $\frac{r_1}{r_2} = \frac{1}{2}; \frac{s_1}{s_2} = \frac{2}{3}; \frac{\rho_1}{\rho_2} = \frac{3}{4}$

The ratio of thermal capcities $= \left(\frac{1}{2}\right)^2\left(\frac{3}{4}\right)\left(\frac{2}{3}\right) = \frac{1}{16}$

Ex 3: The densities of two substances are in the ratio 5 :6 and the specific heats are in the ratio 3:5 respectively. Find the ratio of their thermal capacities per unit volume.

Sol: Given that the ratio of the densities = 5:6

the ratio of the specific heats =3:5

then the ratio of the thermal capacites per unit volume =?

$$H = m.s = vol\times d\times s \Rightarrow H/V = d.s \quad [\because \text{d=m/v} \Rightarrow \text{m=v.d}]$$

$$\frac{H_1/V_1}{H_2/V_2} = \frac{d_1s_1}{d_2s_2} = \frac{5}{6}.\frac{3}{5} = \frac{1}{2}$$

Ex 4: Two lead spheres at the same temperature have radii in the ratio 1:2. What is the ratio of the their heat capacities.

Sol: Given that the ratio of the radii of the lead spheres =1:2

then the ratio of the Heat capacity $\left(H_1 : H_2\right) = ?$

we know that $\mathrm{H=d.v.s}$

$$\Rightarrow H \propto \mathrm{v} \quad \Rightarrow H \propto r^3 \quad \left[\because \mathrm{V} = \frac{4}{3}\pi \mathrm{r}^3\right] \text{(or)} \quad \frac{H_1}{H_2} = \left[\frac{r_1}{r_2}\right]^3 = \left[\frac{1}{2}\right]^3 = \frac{1}{8}$$

Ex 5: The thermal capacity of 10 g of a substance is 8 calorie/^{0}C. What is the specific heat. ($J = 4.2 J/cal$)

Sol: Given that mass of the substance (m) = 10g
thermal capacity (H) = 8cal; J=4.2 J/cal

$$H = ms \Rightarrow s = \frac{H}{m} \Rightarrow \frac{8}{10} = \frac{4}{5} cal/g/^o C = \frac{4}{5\times10^{-3}} 4.2 J/kgK$$

$$= \frac{16.8}{5\times10^{-3}} J/kgK = 3360 J/kgK$$

TEACHING TASK

I. Single correct option questions:

1. The ratio of densities of two substances is 2 : 3 and that of specific heats is 1 : 2. The ratio of thermal capacities per unit volume is
   A) 1 : 2 B) 2 : 1 C) 1 : 3 D) 3 : 1
2. The density of a substance is 400 kgm^{-3} and that of another substance is 600 kgm^{-3} The heat capacity of 40 c.c of first substance is equal to that of 30 c.c of second substance. The ratio of their specific heats is
   A) 1 : 6 B) 6 : 1 C) 9 : 8 D) 8 : 9
3. A body absorbs 1000 calories of heat when it is heated from 20^{0}C to 70^{0}C. The water equivalent of the body is
   A) 10 g B) 15 g C) 20 g D) 25 g
4. Two spheres of copper of diameters 10cm and 20 cm will have thermal capacities in the ratio mass one kilogram is
   A) 1/8 B) 1/2 C) 1/4 D) 1/6
5. The thermal capacity of 100g lead shot is (specific heat of lead is 0.03 cal/g/^{0}C)
   A) 3 cal/^{0}C B) 30 cal/^{0}C C) 300 cal/^{0}C D) 0.3 cal/^{0}C
6. Two spheres have their radii in the ratio1:2 the densities of their materials are in the ratio 2:3 and their specific heats are in the ratio 3:4, then the ratio of their thermal capacities is
   A) 3 : 4 B)1 :16 C) 2 : 3 D)1 : 1
7. The densities of two substances are in the ratio 3 : 4 and their specific heats are in the ratio 2 3.The ratio of thermal capacities per unit volume of these substances is
   A) 2 : 3 B) 3 : 4 C) 1 : 1 D) 1 : 2
8. Two liquids A and B of equal volumes have their specific heats in the ratio 2 : 3. If they have same thermal capacity, then the ratio of their densities is
   A) 1 : 1 B) 2 : 3 C) 3 : 2 D) 5 : 6

II. More than one correct option questions

9. Choose the correct statement(s).
   a) Specific heat of a substance is equal to thermal capacity of 1 g of same substance.
   b) Specific heat of a substance is product of mass and thermal capacity.
   c) Specific heat of a substance does not depend on mass of the body
   d) Heat capacity depends on mass of the body
   A) a,b,c B) a,b C) a,c,d D) all

10. Choose the correct option
   If specific heat of copper is 0.4 J/g^{0}C, then
   a) Thermal capacity of 10g of copper is 4 J/^{0}C
   b) Thermal capacity of 10g of copper is 42 J/^{0}C
   c) If Thermal capacity is 400J/^{0}C then mass of copper taken is 1kg
   d) If Thermal capacity is 400J/^{0}C then mass of copper taken is 100g
   A) a,c B) a,b C) a,b,d D) all

Assertion - A and Reason - R:

   A) Both A and R are true and R is the correct explanation for A.
   B) Both A and R are true and R is not correct explanation of A.
   C) A is true but R is false. D) A is false but R is true

11. A: Specific latent heat of fusion of a substance is the quantity of heatrequired to convert unit mass of the substance from solid to liquid state, without any rise temperature .
   R: Specific latent heat of vapourisation of a substance is the quantity of heat required to convert unit mass of the substance from liquid to solid state.

12. A: Unit of thermal heat capacity is cal $g^{-1}{}^0c^{-1}$
   R: Unit of thermal heat capacity is J K^{-1}

Match the following.

13.

Column-I	**Column-II**
a) Specific heat	1) depends on mass
b) Heat capacity	2) doesn't depend on mass
c) Water equivalent	3) flows from hot body to cold body
d) Heat	4) numerically equal to thermal capacity

   A) a-1,b-4,c-2,d-3 B) a-3,b-1,c-2,d-4 C) a-2,b-1,c-4,d-3 D) a-4,b-1,c-3,d-2

Comprehension type questions:

14. Heat capacity = heat required to rise the temperature of a given body through 1^{0}C, i.e., H = mC
   i) Find the heat capacity of lead of mass 300g? (sp. Heat of lead = 0.03 cal/g^{0}C)
   A) 10 cal/^{0}C B) 12 cal/^{0}C C) 9 cal/^{0}C D) 20 cal/^{0}C
   ii) Find the heat capacity of hydrogen of mass 300g?
   (sp.Heat of hydrogen = 3.5 cal/g^{0}C)
   A) 500 cal/^{0}C B) 1050 cal/^{0}C C) 900 cal/^{0}C D) 200 cal/^{0}C
   iii) If heat capacity of copper of mass 2 kg is 100 cal/^{0}C then specific heat capacity of copper is _____
   A) 0.1 cal/g^{0}C B) 0.05 cal/g^{0}C C) 0.3 cal/g^{0}C D) 0.4 cal/g^{0}C

Fill in the blanks:

15. SI unit of specific heat is .....
16. The heat capacity of 10 g of water is .....

17. 1 cal/g^{0}C = ... J/Kg K
18. The SI unit of thermal capacity is .....
19. The liquid with higher specific heat is .....

Key: 1) C, 2) C, 3) C, 4) A, 5) A, 6) B, 7) D, 8) C.9) C, 10) A, 11) C, 12) D, 13) C, 14) i)C, ii) B, iii) B, 15) J/Kg K, 16) 10 cal/^{0}C, 17) 4200 J/kg K, 18) J/K, 19) water

LEARNER'S TASK

BEGINNERS (Level - I)

I. MCQ's with single correct option questions:

1. Four beakers contains same liquid as given below. Which of the following contains the more amount of heat energy.
   A) 80^{0}C, 100 cm^3 B) 90^{0}C, 60 cm^3 C) 50^{0}C, 250 cm^3 D) 70^{0}C, 150 cm^3
2. A body having 1680 J of energy is supplied to 1000g of water.If the entire amount of energy is converted into heat, then rise in the temperature of water is (sp. heat of water = 4200 J/kg^{0}C)
   A) 0.4^{0}C B) 40^{0}C C) 4^{0}C D) 44^{0}C
3. The ratio of thermal capacities of two aluminium spheres of radii 8 cm and 16 cm is
   A) 4 : 1 B) 1 : 4 C) 1 : 8 D) 8 : 1
4. How much heat is required to rise the temperature of 100 g of water from 5^{0}C to 95^{0}C
   A) 900 kcal B) 90 kcal C) 10 kcal D) 9 kcal
5. How much heat is required to rise the tmeperature of 150 g of iron from 20^{0}C to 25^{0}C (specific heat of iron = 480 J/kg^{0}C)
   A) 350 J B) 345 J C) 360 J D) 330 J
6. 2000 cal of heat supplied to 200 g of water. Find the rise in temperature of water (specific heat of water = 1 cal/g^{0}C)
   A) 10^{0}C B) 20^{0}C C) 30^{0}C D) 40^{0}C
7. How much amount of heat is required to rise the temperature of 100 g of water from 30^{0}C to 100^{0}C.
   A) 25.5 kJ B) 29.4 kJ C) 30 kJ D) 40 kJ
8. 500 g of hot water at 60^{0}C is kept in the open till its tmeperature falls to 40^{0}C. Calculate the heat energy lost to the surroundings by the water.
   A) 2400 J B) 5000 J C) 40000 J D) 42000 J
9. Find heat lost by the copper cube of mass 400 g when it cools from 100^{0}C to 30^{0}C. (specific heat of copper 390 Jkg^{-1} ^{0}C^{-1})
   A) 50000 J B) 10000 J C) 10920J D) 10900 J
10. What quantitiy of heat would be given out by 200g of copper in cooling from 80^{0}C to 20^{0}C (specific heat of copper 0.09 cal/g^{0}C)
    A) 1080 cal B) 1000 cal C) 1500 cal D) 1100 cal

ACHIEVERS (Level - II)

II. More than one correct option questions

11. Factors on which heat absorbed by a body depends
    a) Mass of the body b) Change in temperature of the body
    c) Area of the body d) Nature of the material of the body
    A) a,b,c correct B) a,b correct C) a,b,d correct D) all correct

12. Choose the correct option
a) the S.I. unit of latent heat is J Kg^{-1} b) the C.G.S unit of latent heat is cal g^{-1}
c) the latent heat of substance is denoted with letter 'L'
d) the quantity of heat is denoted with letter 'Q'.
A) a,b,c B) a,b C) a,b,d D) all

13. Pick out the wrong option
a) during change of state heat absorbed or evolved is given by Q=mL.
b) during raise of temperature heat absorbed or evolved is given by Q = m.C. Δt
c) during change of state heat absorbed or evolved is given by Q= m/L
d) during raise of temperature heat absorbed or evolved is given by $Q = \frac{C}{m\Delta T}$
A) a,b,c B) a,b C) c,d D) all

III. Assertion - A and Reason - R:

A) Both A and R are true and R is the correct explanation for A.
B) Both A and R are true and R is not correct explanation of A.
C) A is true but R is false. D) A is false but R is true

14. A: Unit of specific heat is cal $g^{-1}\,{}^0c^{-1}$
R: Unit of specific heat is J K^{-1}

15. A: Water has highest Specific heat among solids and liquids.
R: The amount of heat energy required to raise the temperature of unit mass of a substance through 1K is called specific heat capacity.

IV. Match the following.

16.

Physical quantity	**S.I unit**
a) Specific heat	1) Jk^{-1}
b) Heat capacity	2) $\mathrm{J\,kg^{-1}k^{-1}}$
c) Water equivalent	3) kg
d) Heat lost or gained	4) J

A) a-1,b-4,c-2,d-3 B) a-3,b-1,c-2,d-4
C) a-2,b-1,c-3,d-4 D) a-4,b-1,c-3,d-2

17.

Column-I	**Column-II**
a) unit of specific heat capacity	1) Mass
b) unit of thermal capacity	2) Highest specific heat
c) $\frac{\text{Heat capacity}}{\text{Specific heat capacity}} =$	3) Jk^{-1}
d) Water	4) $\mathrm{J\,kg^{-1}k^{-1}}$

A) a-1,b-4,c-2,d-3 B) a-3,b-1,c-2,d-4
C) a-2,b-1,c-4,d-3 D) a-4,b-3,c-1,d-2

V. Comprehension type questions:

18. $\text{Specificheat} = \frac{\text{quantity of heat}}{\text{mass of the substance} \times \text{change in temperature}}$

i) If specific heat of copper is 0.4 J/g^{0}C,the thermal heat capacity of 100g of the copper is
A) 40 J/^{0}C B) 12 J/^{0}C C) 9 J/^{0}C D) 20 J/^{0}C
ii) Which among the following has highest specific heat capacity value
A) mercury B) copper C) Water D) palm oil
iii) 2cal =..... J
A) 4.2 B) 8.4 C) 2.1 D) none

Key: 1) C, 2) A, 3) C, 4) D, 5) C, 6) A, 7) B, 8) D.9) C, 10) A, 11) C, 12) D, 13) C, 14) C, 15) B, 16) C, 17) D, 18) i) A, ii) C,iii) B.

VI. Fill in the blanks:

1. Heat always flows from body at ..... temperature to body at ..... temperature
2. SI unit of water equivalent is .....
3. Specific heat capacity of ice ..... cal/g^{0}C
4. 1 cal = ... J
5. Specific heat capaicity of water is ..... cal/g^{0}C

Key: 1) higher, lower, 2) kg, 3) 0.5, 4) 4.186, 5) 1

EXPLORERS (Level - II)

I. **Solve the following:**

1. A body was supplied 3600 J of heat, express this amount in ergs.
2. A body was supplied 6300 J of heat, express this in kilocalories.
3. How much heat is requird to rise the temperature of 100 g of water from 5^{0}C to 95^{0}C.(given specific heat of water 1 cal/g^{0}C)
4. The specific heat of brass is 0.092 cal g^{-1} ^{0}C^{-1}. Express this value in SI system.
5. How much heat is required to rise the tmeperature of 150 g of iron from 20^{0}C to 25^{0}C (specific heat of iron = 480 Jkg^{-1} ^{0}C^{-1})
6. 500 g of hot water at 60^{0}C is kept in the open air till its temperature falls to 4^{0}C. Calculate its heat energy lost to the surroundings by the water.
7. 500g of oil has a specific heat capacity 1.8J/g^{0}C.What is the heat capacity of theoil.
8. 48.75 J of heat energy is supplied to 75 g of metal when its temperature rises by 1^{0}C. Calculate specific heat capacity of the metal.
9. The densities of two substances are in the ratio 1:2 and their specific heats in the ratio 2:3. Compare their thermal capacities , if their volumes are in the ratio 3:4.

RESEARCHERS (Level - IV)

10. Two substance A and B have their densities, specific heats and volumes in the same ratio of 2 : 3. Find the ratio of the termal capacities.
11. A metal block absorbs 4500 cal of heat when heated from 30^{0}C to 80^{0}C. Its thermal capacity is
12. A copper block A of mass 500 g and specific heat 0.1 cal/g/ ^{0}C is heated from 30^{0}C and to 40^{0}C. Another identical copper block B of same mass is heated from 35^{0}C to 40^{0}C. Ratio of their thermal capacities is....
13. Specific heat of mercury is 0.03 cal/g/ ^{0}C. Its value in S.I. system is
14. There is a cuboid of dimensions l x b x h and thermal capacity k units. On doubling all the dimensions of the cuboid find new thermal capacity.

Key: 1) 3600 x10^7 erg, 2) 1.5 k cal, 3) 9 k cal, 4) 386.4 Jkg^{-1}K^{-1}, 5) 360 J, 6) 42000 J, 7) 900 J/^{0}C, 8) 0.65 J/g^{0}C, 9) 1:4, 10) 8 : 27, 11) 90cal, 12) 1 : 1, 13) 126 J/kg^{0}K, 14) 8 k.