25. Calorimetry

Short Answer

Answer.1

No, heat is not a conserved quantity.

A conserved quantity remains the same before and after the physical event.

Heat is a form of energy, and energy can neither be created nor be destroyed, but can transform from one form to another.

Best example is a thermocouple, where heat energy is transformed into electrical output due to adjoining two dissimilar metals.

From 1st principle of thermodynamics, only the total energy before or after transformation remains constant.

Answer.2

Calorie is defined as amount of heat required to raise Temperature of one gram of water by one degree (Celsius).

Since heat is a form of energy, hence it's required to give 4.185 J of work to 1 gram of water to raise its temperature by 1 Degree Celsius.

If we round off 4.185J to 4J, there will be a change of 0.185J of Work and hence our calculations will go wrong.

Answer.3

Calorimeter is an apparatus used for measuring the amount of heat involved in a chemical reaction or other process.

A calorimeter is kept inside a good heat insulator

If it’s not kept inside the wooden box which acts as insulating Jacket, the heat will be lost to the surrounding through Conduction and this can lead to discrepancy in the desired results.

Answer.4

Yes, heat of the two objects taken together remains constant.

Since the heat given by the hot object is assumed to be equal to the head taken by the cold object, hence no heat is lost to the surroundings which means the heat of the two object (system) taken together remains constant.

Answer.5

Regnault’s apparatus is an excellent apparatus to measure the amount of heat energy required to change the temperature of a solid body by a known amount.

In Regnault’s apparatus the inlet is near the top and the outlet is near the bottom as steam enters at inlet and leaves in liquid phase at outlet.

When the steam enters at inlet, it loses heat, in which a part of steam condenses back to water.

On the other hand, the part of hot steam after losing heat gets denser and moves down towards the bottom.

So outlet must be in bottom as liquid lies below the steam.

Answer.6

When heat is supplied to melt solid or boil liquid, the heat energy is used in breaking the bond forces between the molecules of the solid or liquid to bring them apart until phase gets changed.

Hence the heat energy supplied to molecules is utilized as kinetic energy to overcome the molecular forces keeping the temperature constant.

This is what we call Latent Heat.

Answer.7

The specific heat capacity of a body is defined as the amount of heat required to raise temperature of unit mass of a substance by one unit

(a) The specific heat capacity of melting ice is 0.50cal/g-^{O}C or 2093 J/kg-K.

(b) The specific heat capacity of boiling water is 0.46 cal/g-^{O}C or 1926 J/kg-K.

Answer.8

Steam carries with it the heat of vaporization of the water.

At the same temperature, steam and boiling water don't contain the same amount of energy.

The internal energy of Steam at 100 ^{O}C is greater than boiling water at same temperature.

Hence steam burns more severely than water even though both are at same temperature.

Answer.9

Coastal areas will generally have more moderate temperatures than inland areas because of the heat capacity of the ocean.

Water has a higher heat capacity than soil and rock; hence it takes time to Heat Ocean rather than soil or rocks.

And because of sea retains the head more when the heat exchange takes place between land and sea.

Answer.10

Thermometer is a device to measure temperature of a body which consists of heat and specific heat of the body.

If it has lower heat capacity, it may expand substantially at high temperatures which lead to false readings.

Hence thermometer bulbs should have large heat capacity.

Objective I

Answer.1

The specific heat capacity of a body is defined as the amount of heat required to raise temperature of unit mass of a substance by one unit.

Now, heat capacity of a body varies due to variations in its molecular structure and hence the material of the body.

Answer.2

Water equivalent of a body is defined as quantity of heat that raises the temperature of some substance by some amount, simultaneously raise the same temperature of a certain mass of water.

Mass of an object is measure in Kg so water equivalent has a unit of mass in Kg.

Hence its measured in Kg

Answer.3

When hot liquid is mixed with cold one, the molecules of the hot and cold liquid exchange heat and hence temperature is undefined.

When they share heat, the systems reach equilibrium.

Hence first the result is undefined and then reaches equilibrium.

Answer.4

Calories the unit for amount of heat needed to raise the temperature of 1 g of water from 14.5^{o} to 15.5^{o} at the pressure of 1 atm

Heat is a form of energy and Joule is the unit of energy.

Hence these two units represent same physical quantity.

Answer.5

Heat is a form of energy and work is force applied to a distance.
Now, work done to raise/fall temperature of a body is nothing but heat required to control the temperature, hence both physical quantities can be represented in the same unit.

Answer.6

When two bodies of different temperatures are missed in a calorimeter, the heat gets exchanged between the molecules of the system, but no heat is exchanged in the surrounding in a calorimeter.

Thus, the total internal energy of the bodies remains conserved as external work done is zero.

Answer.7

The net work done is equal to the change in kinetic energy,

Mechanical energy can be converted to heat and vice – versa.

If the mechanical work done *(W)* by an object produces the same temperature change as heat *(H),* then

Mechanical equivalent of heat (J)

= Amount of Work (W) / units of Heat (Q).

We know unit of work and heat is the same, hence it's dimensionless.

Objective II

Answer.1

We know

$$C = \frac{\Delta Q}{M} \Delta T$$

C=heat capacity

ΔQ=heat given

ΔT=change in temperature

As heat capacity is the heat given to the body to raise its temperature by unit degrees.

Heat capacity depends on the material of the body and mass of it.

Answer.2

$$S = \Delta Q/m\Delta T$$

$$C = \Delta Q/n\Delta T$$

n=m/M

s=specific heat capacity

C=molar heat capacity

ΔQ=heat exchange

ΔT=temperature change

m=mass of body

M=molecular mass of body

n=moles of mody

$$\frac{S}{c} = 1/M$$

so;

ratio of S and c will depend on the molecular weight of the body.

Answer.3

Heat transferred, ΔQ=mCΔT

Where,

ΔT=tempeature change

M=mass

C=heat capacity

Thus, form the above relation, we found that the heat capacity of an object is directly dependent on the temperature difference.

Hence, we can say that the when the heat is applied to the solid, temperature of the solid can be zero or positive so the temp will remain constant or will increase when heat is supplied

Answer.4

Heat change, $\Delta Q=mC\Delta T$

Where,

ΔT=tempeature change

M=mass

C=heat capacity

Since the temperature is constant,

$\Delta Q=0$,

The heat supplied might have been supplied to the body was used in the breaking the bond of the molecules, changing the state of the solid.

Thus, the temperature of the solid remains constant. In the period of heat may have been supplied to the body and heat may have been extracted from the body.

Answer.5

Formula used:

$\Delta Q=mC\Delta T$

ΔQ=heat exchange

ΔT=tempeature 4change

M=mass

C=heat capacity

If the temperature of an object rises in a period, then there are two possibilities. The heat may have been supplied to it, leading to an increase of the internal energy of the object, increasing the temperature of the body.

The second possibility is that some work has been done on it, again leading to an increase of the internal energy of the body.

Thus, the temperature can be increased by supplying heat or by doing work on an object.

Answer.6

According the statement “heat and work are equivalent”, heat supplied to the body increases its temperature. Similarly, work done on the body also increases its temperature.

$\Delta Q = mC\Delta T$

ΔQ=heat exchange

ΔT=tempeature change

M=mass

C=heat capacity

When heat is supplied to a body, we do not do work on it.

When we do work on an object, it does not mean we are supplying heat to the body.

Work done can be converted to temperature but increasing temperature cannot do work on an object

Exercises

Answer.1

Given;

Mass of aluminium=0.5kg

mass of water=0.2kg

Mass of iron=0.2kg

temperature of aluminium vessel and water=20^0c

Temp of iron=100^0c

heat capacity of aluminium=910 J/kg-k

heat capacity of iron=470J/kg-k

heat capacity of water=4200J/kg-k

Formula used:

ΔQ=mCΔT

ΔQ=heat exchange

ΔT=tempeature change

M=mass

C=heat capacity

let the dinal temperature of the mixture be T;

so;

$$\textit{Heat gain by aluminum and water} = 0.5 \times 910(T - 293) + 0.2 \times 4200(T - 293)$$

$$\textit{Heat lost by iron} = 0.2 \times 470 \times 373 - T)$$

as

heat gain by aluminum and water=heat loss by iron

$$0.5 \times 910(T - 293) + 0.2 \times 4200(T - 293) = 0.2 \times 470 \times (373 - T)$$

$$(T - 293)(0.5 \times 910 + 0.2 \times 4200) = 0.2 \times 470 \times (373 - T)$$

$$1389T = 414497$$

T=298.41^{0}k

Answer.2
Given:

Mass of iron=100g

water equivalent of calorimeter=10g

Mas of water =240g

temp of surface=0^0c

S_{iron}=470J/kg-k

Formula Used:

ΔQ=mCΔT

ΔQ=heat exchange

ΔT=tempeature change

M=mass

C=heat capacity

Heat gained by water = heat lost by iron

So

$$\frac{10}{1000} \times 470 \times (T - 60) = \frac{250}{1000} \times 4200 \times (60 - 40)$$

$$47T = 44820$$

T=953.61^{0}C

Answer.3

Given:

Temp of A=12° c

Temp of B=19° c

Temp of C=28° c

Formula

used:ΔQ=MCΔT

ΔQ=heat exchange

ΔT=tempeature change

M=mass

C=heat capacity

Now;

When A and B are mixed

$M_A(16-12)=M_B(19-16)$

$M_B=4M_A/3$

Also;

When B and C are mixed

$M_B(23-19)=M_c(28-23)$

$M_B=5M_c/4$

So when A and C are mixed let the final temperature be T

$M_A(T-12)=M_c(28-T)$

$\frac{3}{4}M_B(T-12)=\frac{4}{5}M_B(28-T)$

15T-180=448-16T

T=20.3° C

Answer.4

(a)**Given:**Number of ice cubes = 4Volume of each ice cube = (2 × 2 × 2) = 8 cm^3Density of ice = 900 kg m^{-3}Total mass of ice, m_i = (4×8 ×10^{-6} ×900) = 288×10^{-4} kgLatent heat of fusion of ice, L_i = 3.4 × 10^5 J kg^{-1}Density of the drink = 1000 kg m^{-3}Volume of the drink = 200 mlMass of the drink = (200×10^{-6})×1000 kg

Formula used:

$\Delta Q = MC\Delta T$

ΔQ=heat exchange

ΔT=tempeature change

M=mass

C=heat capacity

Let us first check the heat released when temperature of 200 ml changes from $10^{o}C$ to $0^{o}C$.$H_w = (200\times10^{-6})\times1000\times4200\times(10-0) = 8400$ J

Heat required to change four 8 cm^3 ice cubes into water $(H_i) = m_iL_i = (288\times10^{-4}) \times (3.4\times10^5) = 9792$ J

Since the heat required for melting the four cubes of the ice is greater than the heat released by water ($H_i > H_w$), some ice will remain solid and there will be equilibrium betweenice and water. **Thus, the thermal equilibrium will be attained at 0^{o} C.**

(b)

Formula used:

$\Delta Q = MC\Delta T$

ΔQ=heat exchange

ΔT=tempeature change

M=mass

C=heat capacity

Equilibrium temperature of the cube and the drink = 0°CLet M be the mass of melted ice.Heat released when temperature of 200 ml changes from 10C to 0C is given by$H_w = (200\times10^{-6})\times1000\times4200\times(10-0) = 8400$ J

Thus,$M\times(3.4\times10^5) = 8400$ J

Therefore,**M = 0.0247 Kg = 25 g**

Answer.5

Given

Specific heat capacity of water = 4200 J kg^{-1} $°C^{-1}$

latent heat of vaporization of water = 2.27×10^6 J kg^{-1}.

Formula used:

$\Delta Q = MC\Delta T$

ΔQ=heat exchange

ΔT=tempeature change

M=mass

C=heat capacity

Heat lost per second from the atmosphere = Heat gained by the water

$0.2\times 10^{-3}\times 2.27\times 10^{6}=4200\times(10-0.2\times 10^{-3})\times \Delta T$

$\Delta T=0.01080974°$ C

Therefore time required for 5° change=5/0.01080974=462.5 seconds=7.7 minutes

Answer.6

Given:

iron (density = 8000 kg m^{-3}, specific heat capacity = 470 J kg^{-1} K^{-1})

density of ice = 900 kg m^{-3}

latent heat of fusion of ice = 3.36×10^5 J kg^{-1}.

Formula used:

$\Delta Q = MC\Delta T$

ΔQ=heat exchange

ΔT=tempeature change

M=mass

C=heat capacity

Heat lost by iron= Heat gained by ice

$8000\times$ Volume$\times 470\times T=900\times$ Volume $\times 3.36\times 10^5$

T=80.42° C

Answer.7

Given

Latent heat of fusion of ice = 3.36×10^5 J kg^{-1}

latent heat of vaporization of water = 2.26×10^6 J kg^{-1}

Formula used:

$\Delta Q=MC\Delta T$

ΔQ=heat exchange

ΔT=tempeature change

M=mass

C=heat capacity

Heat lost 1 kg of steam= Heat gained by 1 kg of ice

$3.36\times 10^5+1\times 1000\times T=2.26\times 10^6+1\times 1000\times (100-T)$

This equation gives T>100 therefore we come to know steam is still present.

So making the temp of the mixture to be 100° C

$3.36\times 10^5+1\times 4200\times 100=M\times 2.26\times 10^6$

M=0.3345kg

So mass of steam turned water=0.3345kg

So

Mass of water in mixture=1+0.3345=1.3345kg

Mass of steam left=1-0.3345=0.665kg

Answer.8

Given:

heat capacity of water = 4200 J kg^{-1} K^{-1}.

Formula used:

$\Delta Q = MC\Delta T$

ΔQ=heat exchange

ΔT=tempeature change

M=mass

C=heat capacity

Heat given by heater = heat taken by water

$0.8\times 1000\times t = 20\times 4200\times (35-10)$

t=2625 s=43.75 minutes

Answer.9

Given:

Temperature of tap water=20^0C

Room temp=5^0C

Volume of tank=$0.5m^3$

Mass to lift=10kg

Formula used:

$\Delta Q = MC\Delta T$

ΔQ=heat exchange

ΔT=tempeature change

M=mass

C=heat capacity

Heat liberated by water =work done to lift

$0.5\times 1000\times 4200\times (20-5)=10\times 10\times$ height

Height=315000m=315km

Answer.10

Given:

Mass of bullet=20g

Initial speed = 40m/s

Formula used:

Kinetic energy $=1/2\ mv^2$

Change in kinetic energy=change in internal energy

16J =change in internal internal energy

Answer.11

Given:

Speed of man:5m/s

$\Delta T=10^0C$

Mass of man=50kg

Formula

used:

Kinetic energy =1/2 mv^2

$\Delta Q=MC\Delta T$

ΔQ=heat exchange

ΔT=tempeature change

M=mass

C=heat capacity

Kinetic energy of person = heat absorbed by the water

$625=M\times 4200\times (30-20)$

M=0.01488kg

Answer.12

given:

mass=4kg

height=3m

Formula used:

Potential energi=mgh

M=mass

g=9.8m/s

h=height

so

potential energy=$4\times10\times 3=120$J

energi converted to thermal energy=$0.8\times 120=96$J

thermal energi in calories=96/4.2=22.8 cal **13.**

Answer.13

Given:

Mass of van=1500kg

Speed=15m/s

Time taken to stop=10s

Formula used:

Mechanical energy=kinetic energi=1/2mv^2

M=mass

V=velocity

So

Kinetic energy=1/2× 1500×225=168750J

Average rate of production of thermal energi=energy produced /time

=168750/10 J/s

=4017.8 cal/s

Answer.14

Given:

mass of block=0.1kg

Formula used:

kinetic energy=1/2mv^2

M=mass

V=velocity

Change in kinetic energy = thermal energy developed

$$\frac{0.1(100-25)}{2} = thermal\ energy$$

3.75J=thermal energy developed

Answer.15

Given:

Mass of blocks:10kg and 20kg

Speeds of blocks:10m/s and 20m/s

Formula used:

Momentum=mv

M=mass

V=velocity

Conserving momentum

Momentum initial=momentum final

10× 10-20×20=30× final velocity

Final velocity=10m/s

Thermal energy=change in kinetic energi

$$Thermal\ energy = \frac{1000 + 8000}{2} - \frac{3000}{2}$$

Thermal energy=3000J

Answer.16

Given:

Heat capacity of ball=800 J/K

Formula used:

Potential energy=mgh

M=mass

H=height

$\Delta Q = MC\Delta T$

ΔQ=change in energi

ΔT=change in temperature

C=heat capacity

M=mass

So

Change in poteintial energy=0.5× g× M

Now;

Change in potential energy=change in energy

$5M = MC\Delta T$

$5 = 800\Delta T$

$\mathbf{0.0025^0C = \Delta T}$

Answer.17

Given:

Heat capacity of copper=420J/Kg/K

Formula used: Potential energy=mgh

M=mass

H=height

$\mathbf{\Delta Q = MC\Delta T}$

ΔQ=change in energi

ΔT=change in temperature

C=heat capacity

M=mass

We know that loss in mechanical energy is due to frictional force which is equal to $mg\sin\alpha$

So

Loss in potential energy=thermal energy

$0.2\times g\times .36=0.2\times 420\times \Delta T$

$\Delta T=0.00857$

Answer.18

Given: Density of metal block, d= 6000 kg m^{-3}Mass of metal block, m = 1.2 kgSpring constant of the spring, k = 200 N m^{-1}

Volume of the block, V

=1.2/6000=2×10-4 m3

When the mass is dipped in water, it experiences a buoyant force and in the spring there is potential energy stored in it.

the net force on the block is zero before breaking of the support of the spring, then

balancing forces$kx + V\rho g = mg$ $200x + (2 \times 10^{-4})\times (1000) \times (10) = 12$

=x=12-2200⇒x=10200=0.05 m

The mechanical energy of the block is transferred to both block and water. Let the rise in temperature of the block and the water be ΔT.

Applying conservation of energy, we get

$1/2kx^2+mgh-V\rho gh=m_1s_1\Delta T+m_2s_2\Delta T$

$=1/2\times200\times0.0025+1.2\times10\times40\times 10^{-2}- 2\times 10\text{-}4\times1000\times10\times40\times10^{-2}$

$=260\times 1000\times4200\times\Delta T+1.2\times250\times\Delta T$

$=0.25+4.8-0.8=1092\ \Delta T+300\Delta T$

$=1392\ \Delta T=4.25$

=ΔT=4.251392=0.0030531

ΔT=3×10-3°