QUESTIONS FOR SHORT ANSWER

1. Is heat a conserved quantity ?
2. The calorie is defined as 1 cal = 4·186 joule. Why not as 1 cal = 4 J to make the conversions easy ?
3. A calorimeter is kept in a wooden box to insulate it thermally from the surroundings. Why is it necessary ?
4. In a calorimeter, the heat given by the hot object is assumed to be equal to the heat taken by the cold object. Does it mean that heat of the two objects taken together remains constant ?
5. In Regnault's apparatus for measuring specific heat capacity of a solid, there is an inlet and an outlet in the steam chamber. The inlet is near the top and the outlet is near the bottom. Why is it better than the opposite choice where the inlet is near the bottom and the outlet is near the top ?
6. When a solid melts or a liquid boils, the temperature does not increase even when heat is supplied. Where does the energy go ?
7. What is the specific heat capacity of (a) melting ice (b) boiling water ?
8. A person's skin is more severely burnt when put in contact with 1 g of steam at 100°C than when put in contact with 1 g of water at 100°C. Explain.
9. The atmospheric temperature in the cities on sea-coast change very little. Explain.
10. Should a thermometer bulb have large heat capacity or small heat capacity ?

OBJECTIVE I

1. The specific heat capacity of a body depends on
(a) the heat given (b) the temperature raised
(c) the mass of the body (d) the material of the body.
2. Water equivalent of a body is measured in
(a) kg (b) calorie (c) kelvin (d) m^3.
3. When a hot liquid is mixed with a cold liquid, the temperature of the mixture
(a) first decreases then becomes constant
(b) first increases then becomes constant
(c) continuously increases
(d) is undefined for some time and then becomes nearly constant.
4. Which of the following pairs represent units of the same physical quantity ?
(a) kelvin and joule (b) kelvin and calorie
(c) newton and calorie (d) joule and calorie.
5. Which of the following pairs of physical quantities may be represented in the same unit ?
(a) heat and temperature (b) temperature and mole
(c) heat and work (d) specific heat and heat.
6. Two bodies at different temperatures are mixed in a calorimeter. Which of the following quantities remains conserved ?
(a) sum of the temperatures of the two bodies
(b) total heat of the two bodies
(c) total internal energy of the two bodies
(d) internal energy of each body.
7. The mechanical equivalent of heat
(a) has the same dimension as heat
(b) has the same dimension as work
(c) has the same dimension as energy
(d) is dimensionless.

OBJECTIVE II

1. The heat capacity of a body depends on
(a) the heat given (b) the temperature raised
(c) the mass of the body (d) the material of the body.
2. The ratio of specific heat capacity to molar heat capacity of a body
(a) is a universal constant
(b) depends on the mass of the body
(c) depends on the molecular weight of the body
(d) is dimensionless.
3. If heat is supplied to a solid, its temperature
(a) must increase (b) may increase
(c) may remain constant (d) may decrease.
4. The temperature of a solid object is observed to be constant during a period. In this period
(a) heat may have been supplied to the body
(b) heat may have been extracted from the body
(c) no heat is supplied to the body
(d) no heat is extracted from the body.
5. The temperature of an object is observed to rise in a period. In this period
(a) heat is certainly supplied to it
(b) heat is certainly not supplied to it
(c) heat may have been supplied to it
(d) work may have been done on it.
6. Heat and work are equivalent. This means,
(a) when we supply heat to a body we do work on it
(b) when we do work on a body we supply heat to it
(c) the temperature of a body can be increased by doing work on it
(d) a body kept at rest may be set into motion along a line by supplying heat to it.

EXERCISES

1. An aluminium vessel of mass 0·5 kg contains 0·2 kg of water at 20°C. A block of iron of mass 0·2 kg at 100°C is gently put into the water. Find the equilibrium temperature of the mixture. Specific heat capacities of aluminium, iron and water are 910 J/kg-K, 470 J/kg-K and 4200 J/kg-K respectively.

2. A piece of iron of mass 100 g is kept inside a furnace for a long time and then put in a calorimeter of water equivalent 10 g containing 240 g of water at 20°C. The mixture attains an equilibrium temperature of 60°C. Find the temperature of the furnace. Specific heat capacity of iron = 470 J/kg-°C.

3. The temperatures of equal masses of three different liquids *A*, *B* and *C* are 12°C, 19°C and 28°C respectively. The temperature when *A* and *B* are mixed is 16°C, and when *B* and *C* are mixed, it is 23°C. What will be the temperature when *A* and *C* are mixed?

4. Four 2 cm × 2 cm × 2 cm cubes of ice are taken out from a refrigerator and are put in 200 ml of a drink at 10°C. (a) Find the temperature of the drink when thermal equilibrium is attained in it. (b) If the ice cubes do not melt completely, find the amount melted. Assume that no heat is lost to the outside of the drink and that the container has negligible heat capacity. Density of ice = 900 kg/m ^{3}, density of the drink = 1000 kg/m ^{3}, specific heat capacity of the drink = 4200 J/kg-K, latent heat of fusion of ice = $3·4 \times 10^5$ J/kg.

5. Indian style of cooling drinking water is to keep it in a pitcher having porous walls. Water comes to the outer surface very slowly and evaporates. Most of the energy needed for evaporation is taken from the water itself and the water is cooled down. Assume that a pitcher contains 10 kg of water and 0·2 g of water comes out per second. Assuming no backward heat transfer from the atmosphere to the water, calculate the time in which the temperature decreases by 5°C. Specific heat capacity of water = 4200 J/kg-°C and latent heat of vaporization of water = $2·27 \times 10^6$ J/kg.

6. A cube of iron (density = 8000 kg/m ^{3}, specific heat capacity = 470 J/kg-K) is heated to a high temperature and is placed on a large block of ice at 0°C. The cube melts the ice below it, displaces the water and sinks. In the final equilibrium position, its upper surface just goes inside the ice. Calculate the initial temperature of the cube. Neglect any loss of heat outside the ice and the cube. The density of ice = 900 kg/m ^{3} and the latent heat of fusion of ice = $3·36 \times 10^5$ J/kg.

7. 1 kg of ice at 0°C is mixed with 1 kg of steam at 100°C. What will be the composition of the system when thermal equilibrium is reached? Latent heat of fusion of ice = $3·36 \times 10^5$ J/kg and latent heat of vaporization of water = $2·26 \times 10^6$ J/kg.

8. Calculate the time required to heat 20 kg of water from 10°C to 35°C using an immersion heater rated 1000 W. Assume that 80% of the power input is used to heat the water. Specific heat capacity of water = 4200 J/kg-K.

9. On a winter day the temperature of the tap water is 20°C whereas the room temperature is 5°C. Water is stored in a tank of capacity 0·5 m ^{3} for household use. If it were possible to use the heat liberated by the water to lift a 10 kg mass vertically, how high can it be lifted as the water comes to the room temperature? Take g = 10 m/s ^{2}.

10. A bullet of mass 20 g enters into a fixed wooden block with a speed of 40 m/s and stops in it. Find the change in internal energy during the process.

11. A 50 kg man is running at a speed of 18 km/h. If all the kinetic energy of the man can be used to increase the temperature of water from 20°C to 30°C, how much water can be heated with this energy?

12. A brick weighing 4·0 kg is dropped into a 1·0 m deep river from a height of 2·0 m. Assuming that 80% of the gravitational potential energy is finally converted into thermal energy, find this thermal energy in calorie.

13. A van of mass 1500 kg travelling at a speed of 54 km/h is stopped in 10 s. Assuming that all the mechanical energy lost appears as thermal energy in the brake mechanism, find the average rate of production of thermal energy in cal/s.

14. A block of mass 100 g slides on a rough horizontal surface. If the speed of the block decreases from 10 m/s to 5 m/s, find the thermal energy developed in the process.

15. Two blocks of masses 10 kg and 20 kg moving at speeds of 10 m/s and 20 m/s respectively in opposite directions, approach each other and collide. If the collision is completely inelastic, find the thermal energy developed in the process.

16. A ball is dropped on a floor from a height of 2·0 m. After the collision it rises up to a height of 1·5 m. Assume that 40% of the mechanical energy lost goes as thermal energy into the ball. Calculate the rise in the temperature of the ball in the collision. Heat capacity of the ball is 800 J/K.

17. A copper cube of mass 200 g slides down on a rough inclined plane of inclination 37° at a constant speed. Assume that any loss in mechanical energy goes into the copper block as thermal energy. Find the increase in the temperature of the block as it slides down through 60 cm. Specific heat capacity of copper = 420 J/kg-K.

18. A metal block of density 6000 kg/m ^{3} and mass 1·2 kg is suspended through a spring of spring constant 200 N/m. The spring–block system is dipped in water kept in a vessel. The water has a mass of 260 g and the block is at a height 40 cm above the bottom of the vessel. If the support to the spring is broken, what will be the rise in the temperature of the water. Specific heat capacity of the block is 250 J/kg-K and that of water is 4200 J/kg-K. Heat capacities of the vessel and the spring are negligible.

ANSWERS

OBJECTIVE I

1. (d) 2. (a) 3. (d) 4. (d) 5. (c) 6. (c)
7. (d)

OBJECTIVE II

1. (c), (d) 2. (c) 3. (b), (c)
4. (a), (b) 5. (c), (d) 6. (c)

EXERCISES

1. 25°C
2. 950°C
3. 20·3°C
4. (a) 0°C (b) 25 g
5. 7·7 min
6. 80°C
7. 665 g steam and 1·335 kg water
8. 44 min
9. 315 km
10. 16 J
11. 15 g
12. 23 cal
13. 4000 cal/s
14. 3·75 J
15. 3000 J
16. $2·5 \times 10^{-3}$°C
17. $8·6 \times 10^{-3}$°C
18. 0·003°C

□

CHAPTER – 25
CALORIMETRY

1. Mass of aluminium = 0.5kg, Mass of water = 0.2 kg
   Mass of Iron = 0.2 kg Temp. of aluminium and water = 20°C = 297°k
   Sp heat o f Iron = 100°C = 373°k. Sp heat of aluminium = 910J/kg-k
   Sp heat of Iron = 470J/kg-k Sp heat of water = 4200J/kg-k
   Heat again = 0.5 × 910(T – 293) + 0.2 × 4200 × (343 –T)
   = (T – 292) (0.5 × 910 + 0.2 × 4200) Heat lost = 0.2 × 470 × (373 – T)
   ∴ Heat gain = Heat lost
   $\Rightarrow$ (T – 292) (0.5 × 910 + 0.2 × 4200) = 0.2 × 470 × (373 – T)
   $\Rightarrow$ (T – 293) (455 + 8400) = 49(373 – T)
   $\Rightarrow (T - 293)\left(\frac{1295}{94}\right) = (373 - T)$
   $\Rightarrow$ (T – 293) × 14 = 373 – T
   $\Rightarrow T = \frac{4475}{15} = 298$ k
   ∴ T = 298 – 273 = 25°C. The final temp = 25°C.
2. mass of Iron = 100g water Eq of caloriemeter = 10g
   mass of water = 240g Let the Temp. of surface = 0°C
   S_{iron} = 470J/kg°C Total heat gained = Total heat lost.
   So, $\frac{100}{1000} \times 470 \times (\theta - 60) = \frac{250}{1000} \times 4200 \times (60 - 20)$
   $\Rightarrow 47\theta - 47 \times 60 = 25 \times 42 \times 40$
   $\Rightarrow \theta = 4200 + \frac{2820}{47} = \frac{44820}{47} = 953.61°C$
3. The temp. of A = 12°C The temp. of B = 19°C
   The temp. of C = 28°C The temp of $\Rightarrow$ A + B = 16°
   The temp. of $\Rightarrow$ B + C = 23°
   In accordance with the principle of caloriemetry when A & B are mixed
   M_{CA} (16 – 12) = M_{CB} (19 – 16) $\Rightarrow$ CA4 = CB3 $\Rightarrow CA = \frac{3}{4}CB$ …(1)
   And when B & C are mixed
   M_{CB} (23 – 19)= M_{CC} (28 – 23) $\Rightarrow$ 4CB = 5CC $\Rightarrow CC = \frac{4}{5}CB$ …(2)
   When A & c are mixed, if T is the common temperature of mixture
   M_{CA} (T – 12) = M_{CC} (28 – T)
   $\Rightarrow \left(\frac{3}{4}\right)CB(T - 12) = \left(\frac{4}{5}\right)CB(28 - T)$
   $\Rightarrow$ 15T – 180 = 448 – 16T
   $\Rightarrow T = \frac{628}{31} = 20.258°C = 20.3°C$

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