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NCERT Solution For Class 11 Physics Chapter 11 Thermal Property of Matter

Q.1: The triple points of neon and carbon dioxide are 24.57 K and 216.55 K respectively. Express these temperatures on the Celsius and Fahrenheit scales.

Ans:

Given: Kelvin and Celsius scales are related as:

$T_C = T_K - 273.15$ .... **(1)**

We know :

$T_F = \left(\frac{9}{5}\right) T_c + 32$ .... **(2)**

For neon:

$T_K = 24.57$ **K**

$\Rightarrow T_C = 24.57 - 273.15 = -248.58^0$ **C**

$T_F = \left(\frac{9}{5}\right) T_c + 32 =$

$\left(\frac{9}{5}\right) \times (-248.58) + 32 = -415.44^0$**F**

For carbon dioxide :

$T_K = 216.55$ **K**

$\Rightarrow T_C = 216.55 - 273.15 = -56.60^0$ **C**

$T_F = \left(\frac{9}{5}\right) T_c + 32 =$

$\left(\frac{9}{5}\right) \times (-56.60) + 32 = -69.88^0$ **F**

Q.2: Two absolute scales A and B have triple points of water defined to be 200 A and 350 B. What is the relation between TA and TB ?

Ans:

Given:

Triple point of water on **absolute scale B, T_2 = 400 B**

Triple point of water on **absolute scale A, T_1 = 200 A**

Triple point of water on **Kelvin scale, T_K = 273.15 K**

273.15 K on the Kelvin scale is equivalent to 200 A on absolute scale A.

$\Rightarrow T_1 = T_K$

200 A = 273.15 K

Thus, A = $\frac{273.15}{200}$

273.15 K on the Kelvin scale is equivalent to 350 B on absolute scale B.

$\Rightarrow T_2 = T_K$

350 B = 273.15 K

Thus, B =

$\frac{273.15}{350}$

Let, **T_A and T_B be the triple point** of water on **scale A and B** respectively.

Thus, we have :

$$273.15 \times \frac{T_A}{200} = 273.15 \times \frac{T_B}{200}$$

Therefore, $T_A : T_B$ = 4 : 7

Q.3: The electrical resistance in ohms of a certain thermometer varies with temperature according to the approximate law :
R = Ro [1 + α (T – To)]
The resistance is 101.6 Ω at the triple-point of water 273.16 K, and 165.5 Ω at the normal melting point of lead (600.5 K). What is the temperature when the resistance is 123.4 Ω?

Ans:

Given:
$R = R_0$ [1 + α (T – T_0)] . . . . (1)
Here, **R_0 and T_0** are **the initial resistance** and **temperature** respectively while **R and T** are **the final resistance and temperature** respectively.
R_0 = 101.6 Ω
T_0 = 273.15 K
Melting point of lead, **T = 600.5 K**

Resistance of lead ,**R = 165.5 Ω**

Using these values in equation (1):

165.5 = 101.6 [1 + α (600.5 – 165.5)]

1.629 = 1 + α (327.35)

Thus, **α =**

$\frac{0.629}{327.35}$ **= 1.92 x 10^{-3} K^{-1}**

Now, **at R = 100 Ω**
100 = 101.6 [(1 + 1.92) x 10^{-3} (T – 273.15)]
0.984 =1 + 1.92 x 10^{-3} (T – 273.15)
-8.3= T – 273.15
Therefore, T = 264.85 K

Q.4: Answer the following :
(a) The triple-point of water is a standard fixed point in modern thermometer. Why? What is wrong in taking the melting point of ice and the boiling point of water as standard fixed points (as was originally done in the Celsius scale)?
(b) There were two fixed points in the original Celsius scale as mentioned above which were assigned the number 0 °C and 100 °C respectively. On the absolute scale, one of the fixed points is the triple-point of water, which on the Kelvin
absolute scale is assigned the number 273.16 K. What is the other fixed point on this (Kelvin) scale?
(c) The absolute temperature (Kelvin scale) T is related to the temperature tc on the Celsius scale by tc = T – 273.15. Why do we have 273.15 in this relation, and not 273.16?
(d) What is the temperature of the triple-point of water on an absolute scale whose unit interval size is equal to that of the Fahrenheit scale?

Ans:

(i) Melting and boiling points of water aren't considered as the standard fixed points because they vary with

change in pressure, the temperature of triple point of water is unique and it does not vary with pressure.
(ii) On the Kelvin's scale there is only a lower fixed point which is 273.16 K, the upper fixed point is not

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there.

(iii) The relation is such because 273.15 K on the Kelvin's scale corresponds to the melting point of ice while 273.16 K is the triple point of water.

(iv) We know,

Relation between the Fahrenheit scale and Absolute scale :

i.e.

$$\frac{T_F - 32}{180} = \frac{T_K - 273}{100} \text{ ....(1)}$$

For another set of T'_F and T'_K

$$\frac{T'_F - 32}{180} = \frac{T'_K - 273}{100} \text{ ....(2)}$$

Subtracting Equation (1) and (2):

$$\frac{T'_F - T_F}{180} = \frac{T'_K - T_K}{100}$$

Therefore, $T'_F - T_F = 1.8(T'_K - T_K)$

For, $T'_K - T_K = 1K$

$\mathbf{T'_F - T_F = 1.8}$

⇒ For the triple point temperature = 273.16 K , **the temperature on the new scale** = 1.8 x 273.16 =

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Q.5: Two ideal gas thermometers A and B use oxygen and hydrogen respectively. The following observations are made :

Temperature	Pressure Thermometer A	Pressure thermometer B
Triple point of water	0.200×10^5 Pa	1.250×10^5 Pa
Melting point of sulfur	0.287×10^5 Pa	1.797×10^5 Pa

(a) What is the absolute temperature of the normal melting point of sulphur as read by thermometers A and B?

(b) What do you think is the reason behind the slight difference in answers of thermometers A and B? (The thermometers are not faulty). What further procedure is needed in the experiment to reduce the discrepancy between the two readings?

Ans. (a)

Given:

At the **triple point of water** i.e., 273.16 K

Pressure in thermometer X, $P_X = 0.200 \times 10^5$ Pa

Let the **melting point** of **sulfur** be T_1

At T_1 **pressure** in X, $P_1 = 0.287 \times 10^5$ Pa

Using Charles' Law :

$$\frac{P_x}{T} = \frac{P_1}{T_1}$$

Thus, $T_1 = T\left(\frac{P_1}{P_x}\right) \Rightarrow T_1 = \frac{0.287 \times 10^5 \times 273.16}{0.2 \times 10^5} = 391.98K$

Now for thermometer Y,

At the **triple point of water** i.e., 273.16 K

Pressure in thermometer Y, $P_Y = 1.250 \times 10^5$ Pa

Let, the **melting point of sulfur be** T_1

At T_1 pressure in Y, $P_1 = 1.797 \times 10^5$ Pa

Using Charles' Law :

$$\frac{P_x}{T} = \frac{P_1}{T_1}$$

Thus, $T_1 = T\left(\frac{P_1}{P_x}\right)$

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$\Rightarrow$ **T_1** = $\frac{1.737 \times 10^5 \times 273.16}{1.250 \times 10^5} = 392.69K$

(b). The slight difference in the readings of the two thermometers is because **the two gases being used in these thermometers, oxygen and hydrogen are not ideal gases.**
To reduce the difference in the values the reading should be taken under lower pressure conditions. **This way these gases behave more like ideal gases.**

Q.6: A steel tape 1m long is correctly calibrated for a temperature of 27.0 °C. The length of a steel rod measured by this tape is found to be 63.0 cm on a hot day when the temperature is 45.0 °C. What is the actual length of the steel rod on that day ? What is the length of the same steel rod on a day when the temperature is 27.0 °C ? Coefficient of linear expansion of steel = 1.20 × 10^{-5} K^{-1}

Ans.

Given:

Length of the metallic tape at temperature T = $25°$ C, l = 1 m = **100 cm**

At temperature T_1 = 45°C
The length of the steel rod, l_1 = 60 cm
Coefficient of linear expansion of the metal (measuring tape), **α = 1.20 × 10^{-5} K^{-1}**
Let **l_2 be the real length of the steel rod and l' be the measuring tape's length at 45 °C.**
i.e. l' = l + α(T_1 – T)

$\Rightarrow$ l' = 100 + 1.20 × 10^{-5}x 100(45 – 25) = **100.024 cm**

Thus the **real length of the steel measured by the tape is :**

l_2 = 60 x $\frac{100.024}{100}$

= 60.0144 cm
And at 25 ^{0}C length of the rod is 60cm.

Q.7: A large steel wheel is to be fitted on to a shaft of the same material. At 27 °C, the outer diameter of the shaft is 8.70 cm and the diameter of the central hole in the wheel is 8.69 cm. The shaft is cooled using 'dry ice'. At what temperature of the shaft does the wheel slip on the shaft? Assume coefficient of linear expansion of the steel to be constant over the required temperature range : αsteel = 1.20 × 10^{-5} K^{-1}.

Ans:

Given:
Temperature, T = 27°C

$\Rightarrow$ 27 + 273 = **300 K**

Coefficient of linear expansion of steel, **α = 1.20 × 10^{-5} K^{-1}**
At temperature T:
Outer diameter of the steel rod **d_1 = 8 cm**
Diameter of the central hole in the disc, **d_2 = 7.99 cm**
Let the temperature be cooled to **T_1** at which the rod will be able to fit in the central hole:
i.e., **Δd** = 7.99 – 8.00 = **– 0.01 cm**

Now, we know:
Δd = d_1α(T_1 – T) = 8 × 1.20 × 10^{-5} (T_1 – 300)

$\Rightarrow$ (T_1 – 300) = -104.16

Therefore, T_1= 195.63 K
=195.63 – 273.16 = – 77.53°C
Hence, the rod will fit into the disc's central whole when its temperature is -77.53 ^{0}C

Q.8: A hole is drilled in a copper sheet. The diameter of the hole is 4.24 cm at 27.0 °C. What is the

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change in the diameter of the hole when the sheet is heated to 227 °C? Coefficient of linear expansion of copper = 1.70 × 10−5 K−1

Ans:

Given:
Initial temperature, T_1 = 27.0°C
Diameter of the hole at T_1 , d_1 = 4.00 cm

At T_1 area of the hole, A_1 = $\pi\left(\frac{d_1^2}{4}\right)$

Final temperature, T_2 = 227°C
Let, the diameter of the hole at **T_2** be **d_2**

At T_2 area of the hole, A_2 = $\pi\left(\frac{d_2^2}{4}\right)$

Co-efficient of linear expansion of copper, **α = 1.70 × 10^{-5} K^{-1}**
We know, co-efficient of **superficial expansion β = 2α = 3.1 x 10^{-5}**
Also, **increase in area** = $A_2 - A_1$**= β α ΔT**
Or, **A_2 = β α ΔT + A_1**

$$\frac{\pi d_2^2}{4} = \frac{\pi}{4}(4)^2\left[1 + 3.4 \times 10^{-5}(228 - 27)\right]$$

$$d_2^2 = 4^2 \times 1.0068$$

$\Rightarrow d_2 = 4.0136$

Thus the change in diameter is = 4.013 − 4 = 0.0136 cm.

Q-9: A brass wire 1.8 m long at 27 °C is held taut with little tension between two rigid supports. If the wire is cooled to a temperature of −39 °C, what is the tension developed in the wire, if its diameter is 2.0 mm ? Co-efficient of linear expansion of brass = 2.0 × 10^{-5} K^{-1}; Young's modulus of brass = 0.91 × 10^{11} Pa.ns:

Given:
Initial temperature, T_1 = 27°C
At T_1 :
length of the brass wire, l = 2 m
Diameter of the wire, d = 2.5 mm = 2.5 × 10^{-3} m
Final temperature, T_2 = 39°C
Let the **tension developed** in the wire = **F**
Coefficient of linear expansion of brass, **α = 2.0 × 10^{-5} K^{-1}**
Young's modulus of brass, Y = 0.91 × 10^{11} Pa

We know, **Young's modulus = Stress / Strain =** $\frac{F \times L}{A \times \Delta L}$

Or, $\Delta L = \frac{F \times L}{A \times Y}$ ....(1)

Where, $\Delta L = \alpha L\,(T_2 - T_1)$ ....(2)

Using equation (2) in (1) we have :

$$\alpha L(T_2 - T_1) = \frac{FL}{\pi\left(\frac{d}{2}\right)^2 \times Y}$$

$$F = \alpha(T_2 - T_1)\pi Y\left(\frac{d}{2}\right)^2$$

$$F = 2 \times 10^{-5} \times (-39 - 27) \times 3.14 \times 0.91 \times 10^{11} \times \left(\frac{2.5 \times 10^{-3}}{2}\right)^2$$

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Therefore the tension, F = -5.893×10^2 N [The negative sign indicates that the tension is directed inwards]

Q.10: A brass rod of length 50 cm and diameter 3.0 mm is joined to a steel rod of the same length and diameter. What is the change in length of the combined rod at 250 °C, if the original lengths are at 40.0 °C? Is there a 'thermal stress' developed at the junction ? The ends of the rod are free to expand (Co-efficient of linear expansion of brass = $2.0 \times 10^{-5}\ K^{-1}$, steel = $1.2 \times 10^{-5}\ K^{-1}$).

Ans:

Given:

Initial temperature, T_1 = 40°C
Final temperature, T_2 = 250°C
Change in temperature, $\Delta T = T_2 - T_1$= 210°C
Coefficient of linear expansion of brass, $\alpha_1 = 2.0 \times 10^{-5}\ K^{-1}$
Coefficient of linear expansion of steel, $\alpha_2 = 1.2 \times 10^{-5}\ K^{-1}$
At T_1 length of the brass rod , l_B = 80 cm = l_S, length of steel rod
At T_1 diameter of the brass rod, d_B = 2.0 mm = d_S, diameter of brass rod.
Now, change in the length of the brass rod $\Delta l_B = \alpha_B \times l_B \times \Delta T = 2.0 \times 10^{-5} \times 80 \times 210$ = 0.36 m
Now, change in the length of the steel rod $\Delta l_S = \alpha_S \times l_S \times \Delta T = 1.2 \times 10^{-5} \times 210 \times 80$ = 0.2016 m
Therefore total change in the length of the rod = 0.36 + 0.2016 = 0.5616 cm
As the rods are free to expand from their ends, no thermal stress is developed in the junction.

Q-11: The coefficient of volume expansion of glycerine is 49 × 10–5 K–1. What is the fractional change in its density for a 30 °C rise in temperature?

Ans:

Given:

Coefficient of volume expansion of glycerin, $\alpha_V = 49 \times 10^{-5}\ K^{-1}$
Rise in temperature, ΔT = 30°C

Fractional change in volume = $\frac{\Delta V}{V}$

We know:

$\alpha_V \Delta T = \frac{\Delta V}{V}$

Or, $V_{T_2} - V_{T_1} = V_{T_1} \alpha_v \Delta T$

Or,

$\frac{m}{\rho_{T_2}} - \frac{m}{\rho_{T_1}} = \frac{m}{\rho_{T_1}} \alpha_v \Delta T$

Where, m = mass of glycerin

ρ_{T_2} = Final density at T_2

ρ_{T_1} = Initial density at T_1

$\Rightarrow \frac{\rho_{T_1} - \rho_{T_2}}{\rho_{T_2}}$ = Fractional change in density

Therefore, Fractional change in density = 1.47×10^{-2}

Q.12: A drilling machine with a power rating of 20 kW is drilling a hole in a 10 kg aluminum block . What is the increase in temperature of the block in 2.5 minutes, considering that 50% of the power is lost in heating the machine itself and lost to the environment. (Specific heat of aluminum = 0.91 J $g^{-1}\ K^{-1}$)

Ans:

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Given:
Power of the drilling machine, P = 20 kW = **20 × 10^3 W**
Mass of the aluminum block, m = 10 kg = **10× 10^3 g**
Time for which the machine is used, t = 2.5 min = 2.5 × 60 = **150 s**
Specific heat of aluminum, c = 0.91 J g^{-1} K^{-1}
Let , the rise in the temperature = δT
Total energy of the drilling machine = **Power x Time** = 20 × 10^3 × 150 J = **3 x10^6 J**
As 50% of energy is lost

Therefore, Useful energy, δQ = $\frac{50}{100} \times 3 \times 10^6$

= **1.5 x 10^6 J**
Since, δQ = m c δT

Therefore the increase in temperature is, δT = $\frac{\Delta Q}{mc}$

$$\Delta T = \frac{1.5\times10^6}{10\times10^3\times0.91}$$

Therefore, δT = 164.8 °C

Q.13: A copper block of mass 2.5 kg is heated in a furnace to a temperature of 500 °C and then placed on a large ice block. What is the maximum amount of ice that can melt? (Specific heat of copper = 0.39 J g−1 K−1; heat of fusion of water = 335 J g−1).

Ans:

Given:
Mass of the copper block, m = 2.5 kg = 2500 g
Rise in the temperature of the copper block, Δθ = 500°C
Specific heat of copper, C = 0.39 J g^{-1} $°C^{-1}$
The maximum heat the copper block can lose, **Q = m C Δθ** = 3000 × 0.39 × 500 = **5.85 x 10^5 J**
Let, m_1 be the total amount of ice melted by the hot block of copper.
Heat gained by molten ice, Q =m_1 L

Therefore,m_1 = $\frac{Q}{L}$ = $\frac{585000}{335}$ **= 1746 26 g**

Q.14: A metal block of mass 0.10 kg at 160°C is immersed in a copper calorimeter having 150 cm^3 of water at 27^0C .If the temperature of the metal drops to a final value of 50°C, what is the specific heat of the metal? If heat is lost to the environment, is your answer lesser or greater than the real value of the specific heat of the metal? [Copper calorimeter is water equivalent to 0.025 kg].

Ans:

Given;
Mass of the metal, m = 0.10 kg = 100 g
Initial temperature of the metal, T_1 = 160°C
Final temperature of the metal, T_2 = 50°C
Calorimeter has a water equivalent mass, **w = 0.025 kg = 25 g**
Volume (V) of water = 150 cm^3
At temperature T = 27°C
Mass of water, M = 150 × 1 = **150 g**
Fall in the temperature of the metal: **ΔT** = T_1 − T_2 = 160 − 50 = **110 °C**
Specific heat of water, **C_W = 4.186 J/g/K**
Let, the specific heat of the metal = **C**
Heat lost by the metal, **θ = m C ΔT** . . . . **(1)**
Increase **in** the temperature of the calorimeter and water:
ΔT' = 50 − 27 = **23 °C**
Heat gained by the calorimeter and water ;

Δθ' = m C_W ΔT' = (M + w) C_W ΔT' . . . . **(2)**

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We know:

Heat lost by the metal = Heat gained by the calorimeter and water

$\Rightarrow$ **$m\,C\,\Delta T = (M + m')\,C_W\,\Delta T'$**

$100 \times C \times 110 = (150 + 25) \times 4.186 \times 23$

Therefore, specific heat C = 1.53 J/g/K

If heat is lost to the environment then the actual value of the specific heat of this metal will be less than what we have arrived at i.e., 1.53 J/g/K

Q.15: Given below are observations on molar specific heats at room temperature of some common gases.

Gas	Molar Specific Heat C_V (cal mol^{-1} K^{-1})
Chlorine	6.17
Oxygen	5.02
Carbon monoxide	5.01
Nitric oxide	4.99
Nitrogen	4.97
Hydrogen	4.87

Generally the specific heat of a mono atomic gas is 2.92 cal (mol K) $^{-1}$, which is significantly lower from the specific heat of the above gases .Explain.

It can be observed that chlorine has little larger value of specific heat, what could be the reason?

Ans:

The gases in the above list are all diatomic and a diatomic molecule has translational, vibrational and rotational motion. Whereas, a **monoatomic gas** only has translational motion. So to increase the temperature of one mole of a diatomic gas by 1°C, heat needs to supplied to increase translational, rotational and vibrational energy. Thus the above gases have significantly higher specific heats than mono atomic gases

Chlorine has little larger **specific heat** as compared to the others in list because it possess **vibrational motion** as well while the rest only have **rotational and translational motions**.

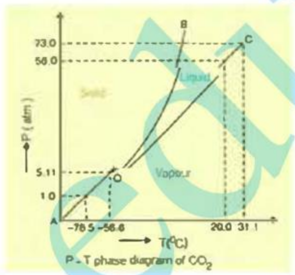
Q.16: Provide answers to the following referring to the P-T phase diagram of CO_2 given below.

(a). What is the temperature where the solid , liquid and vapour states of carbon dioxide co-exits in equilibrium ?

(b). How will decreased pressure affect the boiling and fusion point of CO_2?

(c). State the significance and value of the critical pressure and temperature of carbon dioxide .

(d). Identify the physical state [solid, liquid and vapor] of CO_2 at (i) -72 °C under 1 atm, (ii) 61 °C under 10 atm, (iii) 14 °C under 55 atm.



P - T phase diagram of CO_2

Ans:

(a). At the triple point temperature = 56.6 **°C** and pressure **= 5.11 atm**

(b). Decreased pressure will **decrease** the fusion and boiling point of CO_2.

(c). The **critical pressure and temperature** of carbon dioxide is 73 atm and 31.1 °C respectively. Beyond this temperature carbon dioxide will not be able to **liquefy** no matter how much pressure is exerted.

(d).

(i) At -72 °C and 1 atm CO_2 will be in **the vapor state.**

(ii) At -61 °C and 10 atm CO_2 will be in **the solid state.**

(iii) At 14 °C and 55 atm CO_2 will be **in the liquid state.**

Q.17: Provide answers to the following questions referring to the P-T phase diagram of CO_2 above.
(i). Carbon dioxide at -61 °C and 1 atm pressure is isothermally compressed.
(ii). If carbon dioxide at 4.5 atm pressure is cooled at a constant pressure from the room temperature, what will happen to it?
(iii). State qualitatively the changes in a block of solid carbon dioxide at -60 °C and 10 atm pressure as it is heated up to room temperature at a constant pressure.
(iv). What are the possible changes in the properties of CO_2 when it is isothermally compressed and heated up to 70 °C ?

Ans:

(a). As -61 °C lies to the left of 56.6 °C on the graph i.e., it lies in the vapor and solid state, so CO_2 will directly condense to solid without changing into liquid.

(b). As 4.5 atm is less than 5.11 atm, CO_2 will directly condense into solid without changing into liquid.

(c). When the temperature of the solid block of CO_2 [at 10 atm and -65 °C] is increased, it changes to liquid and then to vapor. If a line parallel to the temperature axis is drawn at 10 atm. The fusion and boiling points of carbon dioxide at 10 atm are given by the points where this parallel line cuts the fusion and vaporization curves.

(d). As **70 °C is higher than the critical temperature,** CO_2 cannot liquefy on being isothermally compressed at this temperature. However with the increase in pressure the gas will drift further away from its ideal behavior.

Q.18: An elderly lady of 60 kg is suffering from a 102 °F fever. She is then given a tablet that lowers fever by increasing the rate of evaporation of sweat from the body. Within 20 minutes her body temperature was lowered to 98 °F . Find the average rate of extra evaporation caused by the tablet assuming that sweat evaporation is the only way for the body to lose heat. Also, the specific heat of a human body is almost the same as that of water, and water's latent heat of evaporation at this temperature is approximately 580 cal /g.

Ans:

Given:
Initial body temperature of the lady, T_1 = 102 °F
Final body temperature of the lady, T_2 = 98 °F
Change in temperature, ΔT = 102 -98 = **4 °F**

$\Rightarrow$ **ΔT =4 x (5/9) = 2.22 °C**

Time taken for the change in temperature, **t = 20 min**
Mass of the child, m = 60 kg = **60×10^3 g**
Specific heat of the human body = Specific heat of water = **c = 1000 cal/kg/ °C**
Latent heat of evaporation of water, **L = 580 cal/ g**
The heat lost by the lady :
$\Delta\theta$ = m C ΔT = 60 x 1000 x 2.22 = **133200 cal**
Let m' be the mass of water that has evaporated from the lady's body in 20 min.
Loss of heat through water :
$\Delta\theta$ = m' L

$m' = \frac{\Delta\Theta}{L} = \frac{133200}{580} = 229.6$ g

Therefore, Average rate of evaporation = $\frac{m'}{t}$

$\Rightarrow \frac{229.6}{20}$ = **11.48 g/min**

Q.19: There is a cubical thermacole ice box of side 20 cm and thickness 4 cm. If 5 kg of ice is kept inside the box, what will be the amount of ice left in the box after 6 h?
[Outside temperature = 45°C, co-efficient of thermal conductivity of thermacole = 0.01 J s^{-1} m^{-1} K^{-1} and heat of fusion of water = 335×10^3 J kg^{-1}]

Ans:

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Given:

Side of the cubical ice box, s = 20 cm **= 0.2 m**

Thickness of the ice box, l = 4.0 cm = **0.04 m**

Mass of ice kept inside the ice box, m = 5 kg

Time gap, t = 6 h = 6 × 60 × 60 s = **21600 s**

Outside temperature, T = 45 °C

Coefficient of thermal conductivity of thermacole, **K = 0.01J s^{-1} m^{-1} K^{-1}**

Heat of fusion of water, **L = 335 × 10^3 J kg^{-1}**

Let **m '** be the total amount of ice that melts in 6 h.

The amount of heat lost by the food kept inside the ice box , $\Theta = \frac{KA(T-0)t}{l}$

Where,
A = Surface area of the box = $6s^2$ = 6 x 0.2^2**= 0.24 m^2**

$$\Rightarrow \quad \Theta = \frac{0.01 \times 0.24(45-0)21600}{0.04} = 58320 \text{ J}$$

Also, we know; **θ = m'L**

Therefore m' = $\frac{58320}{335 \times 10^2}$ **= 0.174 kg**

Thus, the amount of unmolten ice in the box after 6 h = 5 – 0.174 = 4.825 kg

Q.20: A utensil made up of brass has a thickness of 0.5 cm and a base area 0.20 m^2. Water can boil in it at the rate of 6 kg / min when placed over a flame. Calculate the temperature of the flame in contact with the utensil. (Thermal conductivity of brass = 109 J s^{-1} m^{-1} K^{-1}, Heat of vaporization of water = 2256 × 10^3 J kg^{-1})
Ans:

Given:
Base area of the boiler, **A = 0.2 m^2**
Thickness of the boiler, l = 0.5 cm **= 0.005 m**
Boiling rate of water, R = 6.0 kg/min
Mass, m = 6 kg
Time, t = 1 min = **60 s**
Thermal conductivity of brass, **K = 109 J s^{-1} m^{-1} K^{-1}**
Heat of vaporization, **L = 2256 × 10^3 J kg^{-1}**
We know that the amount of heat flowing into water through the brass base is :

$$\Theta = \frac{KA(T-T')t}{l} \ldots\ldots\ldots (1)$$

Where,
T = temperature of the flame in contact with the utensil

T' = boiling point of water = $100°$ C

Heat needed for boiling water :
θ = mL . . . . **(2)**
Equating equation (1) and equation (2):

mL = $\frac{KA(T-T')t}{l}$

T- T' = mLl/Kat = $\frac{6 \times 2256 \times 10^3 \times 0.005}{109 \times 0.2 \times 60}$ = $151.743°$ C

Thus the temperature of the flame in contact with utensil is 151.743 °C

Q.21: Give reasons why:
(a). A body having a large value of reflectivity is a bad emitter.

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(b). On a chilly day a brass spoon feels much colder than a wooden spoon.
(c). The earth without an atmosphere would be extremely cold.
(d). Heating systems using circulating steam are more efficient in heating a building than those using circulating water.
(e). An optical pyrometer (measures high temperatures) calibrated for an ideal black body radiation produces low temperature readings for a red hot iron piece in the open. However, it gives a correct reading when the same piece is in a furnace.

Ans:

(a). A body that is a good reflector is a bad absorber and thus a bad emitter. This is in accordance to Kirchhoff's Law of black body radiations that states poor emitters are poor absorbers and good emitters are good absorbers.
(b). Brass being a better conductor of heat draws greater amount of heat from our hands when we touch it on a chilly day. Wood however does not draw that much amount of heat from us, hence a brass spoon is much colder to touch than a wooden one.
(c). The atmosphere, especially the lower layers , is responsible for reflecting the infrared waves coming from earth back to the surface , thus trapping the heat received during the day. Without an atmosphere, all the heat would have been lost back to space causing our planet to freeze over.
(d). Heating systems using steam are more efficient than those using hot water because at **100 °C steam** has more heat than the same mass of **water at 100 °C.**
(e). An optical pyrometer calibrated for an ideal black body radiation gives too low a value for temperature of a red hot iron piece kept in the open.
Black body radiation equation is given by:
$E = \sigma (T^4 - T_0^4)$
Where,
E = energy radiation
T = temperature of the optical pyrometer
T_0 = Temperature of open space
σ = Constant
We can see that an increase in the temperature of the open space reduces the radiation thereby altering the reading.
However, the same piece of iron when placed in a furnace the radiation energy, $E = \sigma T^4$

Q.22: A hot ball cools from 90 °C to 10 °C in 5 minutes. If the surrounding temperature is 20°C, what is the time taken to cool from 60 °C to 30 °C?

Ans:

Using Newton's law of cooling, the cooling rate is directly proportional to the difference in temperature.

Here, average of 90C and 40 °C = **50 °C**

Surrounding temperature = 20 °C

Difference = 50 – 20= 30° C

Under the given conditions, the ball cools 80° C in 5 minutes

Therefore, $\frac{Change\ in\ temperature}{Time} = k\Delta t \Rightarrow \frac{30}{5}$ = K × 30 . . . . (1)

Where the value of K is a constant.
The average of 60 °C and 30 °C = 45 °C

$\Rightarrow$ 45 °C – 20 °C = 25 °C above the room temperature and the body cools by 30 °C [60 °C – 30 °C]

within time t (Assume)

Therefore, $\frac{30}{t}$ = K × 25 . . . . (2)

Dividing equation (1) by (2), we have:

$\frac{\frac{30}{5}}{\frac{30}{t}} = \frac{K \times 30}{K \times 25} \Rightarrow \frac{t}{5}$ = 1.2

Therefore, t = 6 mins.