Question 11. 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.

Answer: The relation between kelvin scale and Celsius scale is T_K - 273.15 =T_C => T_C=T_K- 273.15

For neon, $T_K = 24.57$ K

$\therefore \quad T_C = 24.57 - 273.15 = -248.58$ °C

For CO_2, $T_K = 216.55$ K

$\therefore \quad T_C = 216.55 - 273.15 = -56.60$ °C

Also, the relation between Kelvin scale and Fahrenheit scale is

$$\frac{T_K - 273.15}{100} = \frac{T_F - 32}{180}$$

$$\therefore \quad T_F = \frac{9}{5}(T_K - 273.15) + 32$$

Now, for neon, $T_K = 24.57$ K

$$\therefore \quad T_F = \frac{9}{5}[24.57 - 273.15] + 32 = -415.44 \text{ °F}$$

For CO_2, $T_K = 216.55$ K

$$\therefore \quad T_F = \frac{9}{5}[216.55 - 273.15] + 32 = -69.88 \text{ °F}$$

Question 11. 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 T_A and T_B ?

Answer: As we know, triple point of water on absolute scale = 273.16 K, Size of one degree of kelvin scale on absolute scale A

$$= \frac{273.16}{200}$$

Value of temperature T_A on absolute scale A

$$= \frac{273.16}{200} T_A$$

Value of temperature T_B on absolute scale B

$$= \frac{273.16}{350} T_B$$

Since T_A and T_B represent the same temperature,

$$\therefore \quad \frac{273.16}{200} T_A = \frac{273.16}{350} T_B$$

$$\text{or} \quad T_A = \frac{200}{350} T_B = \frac{4}{7} T_B.$$

Question 11. 3. The-electrical resistance in ohms of a certain thermometer varies with temperature according to the approximate law: $R = R_0 [1 + \alpha (T - T_0)]$.

The resistances is 101.6 Ωat the triple-point of water 273.16 K, and 165.5 Ωat the normal melting point of lead (600.5 K). What is the temperature when the resistance is 123.4 Ω ?

Answer:

Here, R_0 = 101.6 Ω; T_0 = 273.16 K Case (i) R_1= 165.5 Ω; T_1 = 600.5 K, Case (ii) R_2 = 123.4 , T_2 = ?

Using the relation $R = R_0[1 + \alpha (T - T_0)]$

Case (i) 165.5 = 101.6 [1 + α (600.5 - 273.16)]

$$\alpha = \frac{165.5-101.6}{101.6\times(600.5-273.16)} = \frac{63.9}{101.6\times327\times34}$$

Case (*ii*) $$123.4 = 101.6\ [1 + \alpha\ (T_2 - 273.16)]$$

or $$123.4 = 101.6\left[1+\frac{63.9}{101.6\times327.34}(T_2-273.16)\right]$$

$$= 101.6 + \frac{63.9}{327.34}\ (T_2 - 273.16)$$

or $$T_2 = \frac{(123.4-101.6)\times327.34}{63.9}+273.16 = 111.67 + 273.16$$

$$= \mathbf{384.83\ K}$$

Question 11. 4. Answer the following:
(a) The triple-point of water is a standard fixed point in modem thermometry. 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 t_C on the Celsius scale t_C = 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 ?
Answer:
(a) Triple point of water has a unique value i.e., 273.16 K. The melting point and boiling points of ice and water respectively do not have unique values and change with the change in pressure.
(b) On Kelvin's absolute scale, there is only one fixed point, namely, the triple-point of water and there is no other fixed point.
(c) On Celsius scale 0 °C corresponds to the melting point of ice at normal pressure and the value of absolute temperature is 273.15 K. The temperature 273.16 K corresponds to the triple point of water.
(d) The Fahrenheit scale and Absolute scale are related as

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

For another set of temperature T'_F and T'_K,

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

Subtracting (*i*) from (*ii*)

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

$$\therefore \quad T'_F - T_F = \frac{180}{100}\ (T'_K - T_K)$$

For $$T'_K - T_K = 1\ \text{K},$$

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

∴ For a temperature of triple point *i.e.,* 273.16 K, the temperature on the new scale is

$$= 273.16 \times \frac{180}{100} = 491.688.$$

Question 11. 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	1.250×10^5 Pa	0.200×10^5 Pa
Normal melting point of sulphur	1.797×10^5 Pa	0.287×10^5 Pa

(a) What is the absolute temperature of 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 ?
Answer:
(a) Let T be the melting point of sulphur.
For thermometer A

$$P_{tr} = 1.250 \times 10^5 \text{ Pa}; \quad P = 1.797 \times 10^5 \text{ Pa}$$

Now, $$T_A = T_{tr} \times \frac{P}{P_{tr}}$$

$$T_A = 273.16 \times \frac{1.797 \times 10^5}{1.250 \times 10^5} \text{K} = 392.69 \text{ K}$$

For thermometer B

$$P_{tr} = 0.200 \times 10^5 \text{ Pa}; \quad P = 0.287 \times 10^5 \text{ Pa}$$

$$T_B = T_{tr} \times \frac{P}{P_{tr}} = \frac{273.16 \times 0.287 \times 10^5}{0.200 \times 10^5} \text{K}$$

$$= 391.98 \text{ K}$$

(b) The value of the melting point of sulphur found from the two thermometers differ slightly due to the reason that in practice, the gases do not behave strictly as perfect gases i.e., gases are not perfectly ideal.
To reduce the discrepency, readings should be taken for lower and lower pressures and the plot between temperature measured versus absolute pressure of the gas at triple point should be extrapolated to obtain the temperature in the limit pressure tends to zero (if P —> 0), when the gases approach ideal gas behaviour.

Question 11. 6. A steel tape 1 m 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 = $1.20 \times 10^{-1} K^{-1}$.
Answer: On a day when the temperature is 27 °C, the length of 1 cm division on the steel tape is exactly 1 cm, because the tape has been calibrated for 27 °C.When the temperature rises to 45 °C (that is, $\Delta T = 45 - 27 = 18$ °C), the increase in the length of 1 cm division is $\Delta l = \alpha l \Delta T = (1.2 \times 10^{-5} C^{-1}) \times 1 \text{ cm} \times 18$ °C = 0.000216 cm Therefore, the length of 1 cm division on the tape becomes 1.000216 cm at 45 °C. As the length of the steel rod is read to be 63.0 cm on the steel tape at 45 °C, the actual length of the rod at 45 °C is 63.0 x 1.000216 cm = 63.0136 cm The length of the same rod at 27 °C is 63.0 cm, because 1 cm mark on the steel tape is exactly 1 cm at 27 °C.

Question 11. 7. A large steel wheel is to befitted 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 α_{steel}= $1\text{-}20 \times 10^{-5} K^{-1}$.
Answer:
Here at temperature T_1 = 27 °C, diameter of shaft D_1 = 8.70 cm
Let at temperature T_2, the diameter of shaft changes to D_2 = 8.69 cm and for steel

$$\alpha = 1.20 \times 10^{-5} \text{ K}^{-1} = 1.20 \times 10^{-5} \text{ °C}^{-1}$$

$\because$ Change in diameter $\Delta D = D_2 - D_1 = D_1 \times \alpha \times (T_2 - T_1)$

$\therefore$ $$8.69 - 8.70 = 8.70 \times 1.20 \times 10^{-5} \times (T_2 - 27)$$

$\Rightarrow$ $$T_2 = 27 - \frac{0.01}{8.70 \times 1.20 \times 10^{-5}} = 27 - 95.8 = -68.8 \text{ °C} \quad \text{or} \quad -69 \text{ °C}.$$

Question 11. 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 change in the diameter of the hole when the sheet is heated to 227 °C ? Coefficient of linear expansion of copper = $1.70 \times 10^{-5} K^{-1}$.
Answer:

In this problem superficial expansion of copper sheet will be involved on heating.

Here, area of hole at 27° C, $A_1 = \frac{\pi D_1^2}{4} = \frac{\pi}{4} \times (4.24)^2 \text{ cm}^2$

If D_2 cm is the diameter of the hole at 227 °C, then area of the hole at 227 °C,

$$A_2 = \frac{\pi D_2^2}{4} \text{cm}^2$$

Coefficient of superficial expansion of copper is,

$$\beta = 2\,\alpha = 2 \times 1.70 \times 10^{-5} = 3.4 \times 10^{-5}\ °C^{-1}$$

$$\text{Increase in area} = A_2 - A_1 = \beta A_1\,\Delta T \quad \text{or} \quad A_2 = A_1 + \beta A_1\,\Delta T = A_1\,(1 + \beta\,\Delta T)$$

$$\frac{\pi D_2^2}{4} = \frac{\pi}{4}(4.24)^2\,[1 + 3.4 \times 10^{-5}\,(228 - 27)]$$

$$\Rightarrow \quad D_2^2 = (4.24)^2 \times 1.0068$$

$$\text{or} \quad D_2 = 4.2544 \text{ cm}$$

$$\text{Change in diameter} = D_2 - D_1 = 4.2544 - 4.24 = 0.0144 \text{ cm.}$$

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