



Question 11. 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 = $2.0 \times 10^{-5} \text{K}^{-1}$; Young's modulus of brass = $0.91 \times 10^{11} \text{ Pa}$.

Ans.

Here,

$$l = 1.8 \text{ m},$$

$$\Delta t = (-39 - 27) ^\circ\text{C} = -66 ^\circ\text{C}$$

$$\alpha = 2.0 \times 10^{-5} \text{ K}^{-1}$$

$$Y = 0.91 \times 10^{11} \text{ Pa}$$

$$A = \frac{\pi D^2}{4} = \frac{22}{7} \times \frac{1}{4} (2 \times 10^{-3})^2 \text{ m}^2$$

Now,

$$Y = \frac{Fl}{A\Delta l} \Rightarrow \Delta l = \frac{Fl}{AY} \text{ or } l\alpha\Delta t = \frac{Fl}{AY}$$

or

$$F = -YA\alpha\Delta t$$

or

$$F = -0.91 \times 10^{11} \times \frac{22}{7} \times \frac{1}{4} (2 \times 10^{-3})^2 \times 2.0 \times 10^{-5} \times 66 \text{ N}$$

$$= -3.77 \times 10^2 \text{ N}.$$

Question 11. 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 = $2.0 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$, steel = $1.2 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$).

Ans.

Here, $l_{\text{brass}} = l_{\text{steel}} = 50 \text{ cm}$, $d_{\text{brass}} = d_{\text{steel}} = 3 \text{ mm} = 0.3 \text{ cm}$, $\Delta l_{\text{brass}} = ?$, $\Delta l_{\text{steel}} = ?$

$$\Delta T = 250 - 40 = 210 ^\circ\text{C}.$$

$$\alpha_{\text{brass}} = 2 \times 10^{-5} \text{ }^\circ\text{C}^{-1} \text{ and } \alpha_{\text{steel}} = 1.2 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$$

Now

$$\Delta l_{\text{brass}} = \alpha_{\text{brass}} \times l_{\text{brass}} \times \Delta T$$

$$= 2 \times 10^{-5} \times 50 \times 210 = 0.21 \text{ cm}$$

Now

$$\Delta l_{\text{steel}} = \alpha_{\text{steel}} \times l_{\text{steel}} \times \Delta T$$

$$= 1.2 \times 10^{-5} \times 50 \times 210$$

$$= 0.126 \text{ cm} \approx 0.13 \text{ cm}$$

\therefore Total change in length, $\Delta l = \Delta l_{\text{brass}} + \Delta l_{\text{steel}} = 0.21 + 0.13 = 0.34 \text{ cm}$

Since the rod is not clamped at its ends, no thermal stress is developed at the junction.

Question 11. 11. The coefficient of volume expansion of glycerine is $49 \times 10^{-5} \text{K}^{-1}$. What is the fractional change in its density for a 30 °C rise in temperature ?

Ans.

Here,

$$\gamma = 49 \times 10^{-5} \text{ }^\circ\text{C}^{-1}, \Delta T = 30 ^\circ\text{C}$$

As

$$V = V + \Delta V = V (1 + \gamma \Delta T)$$

\therefore

$$V' = V (1 + 49 \times 10^{-5} \times 30) = 1.0147 V$$

Since

$$\rho = \frac{m}{V}, \rho' = \frac{m}{V'} = \frac{m}{1.0147V} = 0.9855 \rho$$

Fractional change in density = $\frac{\rho - \rho'}{\rho}$

$$= \frac{\rho - 0.9855 \rho}{\rho} = 0.0145.$$

Question 11. 12. A 10 kW drilling machine is used to drill a bore in a small aluminium block of mass 8.0 kg. How much is the rise in temperature of the block in 2.5 minutes, assuming 50% of power is used up in heating the machine itself or lost to the surroundings? Specific heat of aluminium = $0.91 \text{ J g}^{-1} \text{ K}^{-1}$.

Answer:

$$\text{Power} = 10 \text{ kW} = 10^4 \text{ W}$$

$$\text{Mass, } m = 8.0 \text{ kg} = 8 \times 10^3 \text{ g}$$

Rise in temperature, $\Delta T = ?$

$$\text{Time, } t = 2.5 \text{ min} = 2.5 \times 60 = 150 \text{ s}$$

$$\text{Specific heat, } C = 0.91 \text{ J g}^{-1} \text{ K}^{-1}$$

$$\begin{aligned}\text{Total energy} &= \text{Power} \times \text{Time} = 10^4 \times 150 \text{ J} \\ &= 15 \times 10^5 \text{ J}\end{aligned}$$

As 50% of energy is lost,

\therefore Thermal energy available,

$$\Delta Q = \frac{1}{2} \times 15 \times 10^5 = 7.5 \times 10^5 \text{ J}$$

Since

$$\Delta Q = mc\Delta T$$

$$\therefore \Delta T = \frac{\Delta Q}{mc} = \frac{7.5 \times 10^5}{8 \times 10^3 \times 0.91} = 103^\circ \text{ C}.$$

Question 11. 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 is $0.39 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$. Heat of fusion of water = 335 J g^{-1} .

Answer:

Here, mass of copper block, $m = 2.5 \text{ kg} = 2500 \text{ g}$

Fall in temperature, $\Delta T = 500 - 0 = 500^\circ\text{C}$

Specific heat of copper, $c = 0.39 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$

Latent heat of fusion, $L = 335 \text{ J g}^{-1}$

Let the mass of ice melted be m'

As, Heat gained by ice = Heat lost by copper

$$\therefore m' L = mc \Delta T$$

$$m' = \frac{mc \Delta T}{L}$$

$$m' = \frac{2500 \times 0.39 \times 500}{335} = 1500 \text{ g} = 1.5 \text{ kg}$$

Question 11. 14. In an experiment on the specific heat of a metal, a 0.20 kg block of the metal at 150°C is dropped in a copper calorimeter (of water equivalent 0.025 kg) containing 150 cm^3 of water at 27°C . The final temperature is 40°C . Compute the specific heat of the metal. If heat losses to the surroundings are not negligible, is your answer greater or smaller than the actual value for specific heat of the metal?

Answer:

Mass of metal block, $m = 0.20 \text{ kg} = 200 \text{ g}$

Fall in the temperature of metal block,

$$\Delta T = (150 - 40)^\circ\text{C} = 110^\circ\text{C}$$

If C be the specific heat of metal, then heat lost by the metal block =

$$200 \times C \times 110 \text{ cal}$$

Volume of water = 150 cm^3

mass of water = 150 g

Increase in temperature of water = $(40 - 27)^\circ\text{C} = 13^\circ\text{C}$

Heat gained by water = $150 \times 13 \text{ cal}$

Water equivalent of calorimeter,

$$w = 0.025 \text{ kg} = 25 \text{ g}$$

Heat gained by calorimeter,

$$\begin{aligned}&= w \times \text{increase in temperature of calorimeter} \\ &= 25 \times 13 \text{ cal}\end{aligned}$$

Heat lost by metal block

$$= \text{Heat gained by water} + \text{Heat gained by calorimeter}$$

$$200 \times C \times 110 = (150 + 25) \times 13$$

$$C = \frac{175 \times 13}{200 \times 110} = 0.1 \text{ Cal g}^{-1} \text{ }^\circ\text{C}^{-1} = 0.43 \text{ J g}^{-1} \text{ K}^{-1}$$

If heat is lost to the surroundings, C will be smaller than the actual value.

Question 11. 15. Given below are observations on molar specific heats at room temperature of some common gases.

| <i>Gas</i> | <i>Molar specific heat (C_v)</i> <i>(cal mol⁻¹ K⁻¹)</i> |
|------------------------|---|
| <i>Hydrogen</i> | <i>4.87</i> |
| <i>Nitrogen</i> | <i>4.97</i> |
| <i>Oxygen</i> | <i>5.02</i> |
| <i>Nitric oxide</i> | <i>4.99</i> |
| <i>Carbon monoxide</i> | <i>5.01</i> |
| <i>Chlorine</i> | <i>6.17</i> |

The measured molar specific heats of these gases are markedly different from those for mono atomic gases. Typically, molar specific heat of a mono atomic gas is 2.92 cal/mol K. Explain this difference. What can you infer from the somewhat larger (than the rest) value for chlorine ?

Answer: The gases which are listed in the above table are diatomic gases and not mono atomic gases. For diatomic gases, molar specific heat $= \frac{5}{2} R = \frac{5}{2} \times 1.98 = 4.95$, which agrees fairly well with all observations listed in the table except for chlorine. A mono atomic gas molecule has only the translational motion. A diatomic gas molecule, apart from translational motion, the vibrational as well as rotational motion is also possible. Therefore, to raise the temperature of 1 mole of a diatomic gas through 1°C, heat is to be supplied to increase not only translational energy but also rotational and vibrational energies. Hence, molar specific heat of a diatomic gas is greater than that for mono atomic gas. The higher value of molar specific heat of chlorine as compared to hydrogen, nitrogen, oxygen etc. shows that for chlorine molecule, at room temperature vibrational motion also occurs along with translational and rotational motions, whereas other diatomic molecules at room temperature usually have rotational motion apart from their translational motion. This is the reason that chlorine has somewhat larger value of molar specific heat.

Question 11. 16. (a) At what temperature and pressure can the solid, liquid and vapour phases of CO₂ co-exist in equilibrium ?

(b) What is the effect of decrease of pressure on the fusion and boiling point of CO₂ ?

(c) What are the critical temperature and pressure for CO₂ ? What is their significance 1

(d) Is CO₂ solid, liquid or gas at (a) - 70 °C under 1 atm (b) - 60 °C under 10 atm (c) 15°C under 56 atm?

Answer:

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

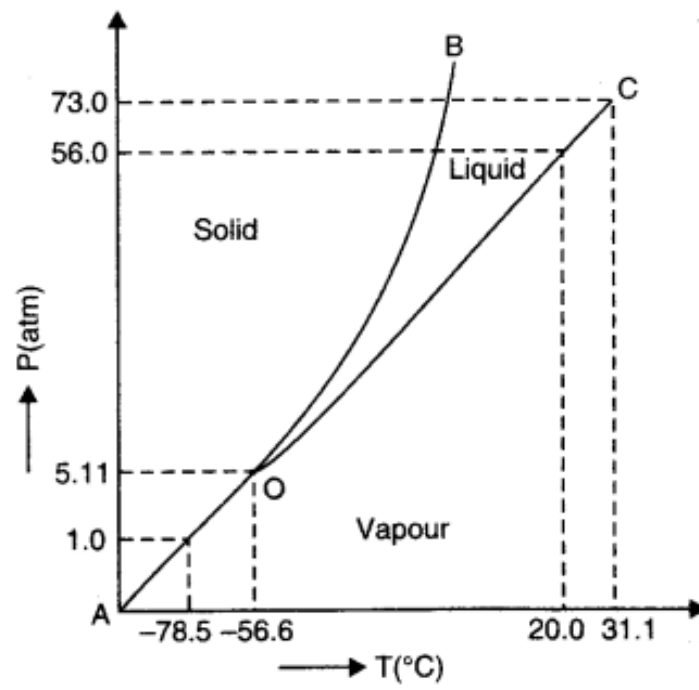
(b) Both the boiling point and freezing point of CO₂ decrease if pressure decreases.

(c) The critical temperature and pressure of CO₂ are 31.1°C and 73.0 atm respectively. Above this temperature, CO₂ will not liquefy/even if compressed to high pressures.

(d) (i) The point (- 70 °C, 1.0 atm) lies in the vapour region. Hence, CO₂ is vapour at this point.

(ii) The point (- 60 °C, 10 atm) lies in the solid region. Hence, CO₂ is solid at this point.

(iii) The point (15 °C, 56 atm) lies in the liquid region. Hence, CO₂ is liquid at this point.



P-T phase diagram of CO₂

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