

Thermal Properties of Matter

ANSWERS

Module 1 Measurement of Temperature and Gas Laws

A.11.1.1 (B)

Option (B) is the statement that describes the conditions which a system in thermal equilibrium should possess. Option (A) refers to the total energy; option (C) does not include composition while option (D) refers to microscopic parameters.

A.11.1.2 (B)

Let the temperature be x

Using the conversion formula $\frac{F-32}{180} = \frac{C}{100}$, we have

$$\frac{x-32}{180} = \frac{x}{100}.$$

Solving we get $x = -40$.

A.11.1.3 (C)

Option (A) is incorrect as the melting point of ice is 0°C and not 0 K .

Option (B) is incorrect as no temperature is possible below 0 K .

Option (D) refers to boiling point of water

A.11.1.4 (B)

Mercury in the bulb requires some time to attain thermal equilibrium with the body.

A.11.1.5 (D) According to Charles' law $\frac{V_1}{T_1} = \frac{V_2}{T_2}$. Therefore,

$$T_2 = T_1 (V_2/V_1),$$

$$\text{or } T_2 = (273 + 57) (1.5) = 495\text{ K}$$

$$495\text{ K} = (495-273)^{\circ}\text{C} = 222^{\circ}\text{C}$$

A.11.1.6 (B)

$$P_{\text{bed}} V_{\text{bed}} = P_{\text{surface}} V_{\text{surface}}$$

Therefore, $P_{\text{bed}} = P_{\text{surface}} = (1 \text{ atm}) (4 \text{ V})$.

Therefore, $P_{\text{bed}} = 4 \text{ atm} = 40 \text{ m of water column}$.

Depth of the lake = 40 m - 10 m = 30 m.

A.11.1.7 (A)

From the kinetic theory of gasses, we know that the internal energy of an ideal gas is zero at 0 K.

But for every substance there is a zero point energy, and its value is non-zero and the least at 0 K.

So, (A) is correct but (B) and (C) are incorrect.

(D) holds for an ideal gas. It is not generally true for any substance.

A.11.1.8 (A)

Use the formula $\frac{F-32}{180} = \frac{K-273.15}{100} = \frac{C}{100}$, we get

Temperature in °C = -248.58

Temperature in K = 24.57

A.11.1.9 (D)

At constant temperature, $P_1 V_1 = P_2 V_2$

or, $V_2 = P_1 V_1 / P_2$

Therefore $V_2 = \text{Volume at } 300 \text{ kPa} = (150 \times 100)/300 = 50 \text{ cm}^3$

A.11.1.10 (C)

$$P = \frac{RT}{V} = \frac{R}{V} (T_0 + c V^2) = \frac{RT_0}{V} + RcV$$

so $P = x + y$ where $x = \frac{RT_0}{V}$ and $y = RcV$

so, $xy = RcT_0 = k = \text{constant}$

Now $(x + y)^2 = (x - y)^2 + 4xy = (x - y)^2 + 4k$

$(x+y)$ is minimum when the perfect square $(x - y)^2 = 0$ or $x = y$

$$\frac{RT_0}{V} = RcV$$

$$V^2 = \frac{T_0}{c}$$

$$V = \left(\frac{T_0}{c}\right)^{1/2}$$

$$\text{so } P_{\min} = \frac{2RT_0}{V} = 2RT_0 \left(\frac{c}{T_0}\right)^{1/2} = 2R(cT_0)^{1/2}$$

which is option(C) .

Module 2 Thermal Expansion

A.11.2.1 (D)

Increase in length of the three rods varies directly as their coefficients of thermal expansion. Initial dimensions and the change in temperature are the same.

A.11.2.2 (C)

Option (C) defines the coefficient of area expansion of the material of the lamina, that is, aluminum. Option (A) and (B) refer to coefficient of linear expansion while option (D) refers to coefficient of expansion of lamina and is therefore incorrect.

A.11.2.3 (C)

The change in length of the brass rod ΔL will be equal to $1000 \text{ mm} \times 50 \text{ }^\circ\text{C} \times 1.8 \times 10^{-5} \text{ K}^{-1} = 0.9 \text{ mm}$.

A.11.2.4 (A)

Use the relation. $\alpha_l = \frac{1}{\Delta T} \frac{\Delta l}{l}$.

A.11.2.5 (C)

Hint: Use the relation. $\alpha_v = \left(\frac{\Delta V}{V}\right) \frac{1}{\Delta T}$.

A.11.2.6 (D)

The extent of bending of a bimetallic strip depends on the difference in the coefficients of linear expansion of its constituent metals. Therefore option (D) is correct.

A.11.2.7 (A)

The tape has been used at 0 °C while it has been calibrated for 20 °C. So, the markings on the tape are closer together. As a result, this measurement is more than the actual length. The error is $2.9 \times 10^{-5} \text{ K}^{-1} \times 25 \text{ m} \times (-20 \text{ K}) = -0.0145 \text{ m}$ (rounded to 0.014). Hence the real distance = $(25 - 0.014) = 24.986 \text{ m}$. So option (A) is correct.

A.11.2.8 (D)

This question tests the knowledge that coefficients of linear expansions of glass and platinum have the same value. For the two materials in options (A), (B) and (C), the coefficients of expansion are different .

A.11.2.9 (B)

Use $\Delta V/V = \alpha_v \times \Delta T = 3 \alpha_L \times \Delta T$

A.11.2.10 (B)

The volume of a gas increases when its temperature is increased. Therefore, the density of a gas decreases with the rise in its temperature.



Module 3 Applications of Thermal Properties of matter

A.11.3.1 (D)

At 0 kelvin both the pressure and volume of an ideal gas are zero.

A.11.3.2 (B)

We have $\Delta Q = m \cdot C \cdot \Delta T$. Therefore, ΔQ depends on both mass and specific heat but not on the shape. However, ΔQ , depends on the initial temperature as the specific heat of a material varies with temperature.

A.11.3.3 (B)

When a gas is heated at constant pressure, a part of the energy supplied is used in doing work for expansion of the gas.

A.11.3.4 (D)

The volume of oil decreases on cooling and the density increases. Hence the fraction of the volume of the oil packet above the water surface decreases.

A.11.3.5 (B)

The SI unit of coefficient of volume expansion is K^{-1} . The SI unit of specific heat and the quantity of heat are $\text{J kg}^{-1} \text{ } ^\circ\text{C}^{-1}$ and J respectively while the unit of boiling point is K or $^\circ\text{C}$.

A.11.3.6 (D)

The specific heat is defined as the quantity of heat required to raise the temperature of unit mass of a substance by unit temperature, that is, $s = \frac{\Delta Q}{m\Delta T}$. Other three options are permutations of the same relation.

A.11.3.7 (B)

The heat gained by 2 kg water at 30°C to attain the temperature T of the mixture will be equal to the heat lost by water at 70°C in attaining the temperature T .

The temperature T of the mixture of water is given by $T = (m_1sT_1 + m_2sT_2) / (m_1s + m_2s)$.

Substituting $m_1 = 2 \text{ kg}$, $m_2 = 8 \text{ kg}$, $T_1 = 70^\circ\text{C}$ and $T_2 = 30^\circ\text{C}$, we get $T = 38^\circ\text{C}$.

A.11.3.8 (D)

Let C_1 and C_2 be the thermal capacities of liquid A and B. From principle of calorimetry

$$C_1(30 - 10) = C_2(60 - 30)$$

$$\therefore \frac{C_1}{C_2} = \frac{3}{2}$$

A.11.3.9 (A)

We know that $C_p > C_v$. The difference y is a positive number. Therefore,

$$C_p - C_v = y \quad (11.3.1)$$

The ratio, z of the two is more than one. Therefore

$$\frac{C_p}{C_v} = z \quad (11.3.2)$$

From Eqs(11.3.1) and (11.3.2), we have

$$C_v = \frac{y}{(z-1)}$$

$$\text{and } C_p = \frac{yz}{(z-1)}$$

A.11.3.10 (D)

Heat capacity is defined as the amount of heat required to raise the temperature of a substance by one unit.

Since the handle of a cooking vessel should not get heated easily, it should have a high heat capacity.

The handle of a cooking vessel should be a thermal insulator hence it should have low conductivity.

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