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Thermal Physics

ANSWERS TO MULTIPLE CHOICE QUESTIONS

1. $T_F = \frac{9}{5}T_C + 32 = \frac{9}{5}(-25°) + 32° = -13°\text{ F}$, and the correct response is choice (e).

2. The correct choice is (b). When an object, containing a cavity, is heated, the cavity expands in the same way as it would if filled with the material making up the rest of the object.

3. $\Delta L = \alpha_{\text{Cu}} L_0 (\Delta T) = \left[17\times10^{-6}\ (°\text{C})^{-1}\right](93\text{ m})(5°\text{C}) = 8\times10^{-3}\text{ m} \sim 10^{-2}\text{ m} = 1\text{ cm}$ and choice (c) is the correct order of magnitude.

4. $T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(162 - 32) = 72.2°\text{C}$, then $T_K = T_C + 273 = 72.2 + 273 = 345\text{ K}$, so choice (c) is the correct answer.

5. Remember that one must use absolute temperatures and pressures in the ideal gas law. Thus, the original temperature is $T_K = T_C + 273.13 = 25.0 + 273.15 = 298.2\text{ K}$, and with the mass of the gas constant, the ideal gas law gives

$$T_2 = \left(\frac{P_2}{P_1}\right)\left(\frac{V_2}{V_1}\right)T_1 = \left(\frac{1.07\times10^6\text{ Pa}}{5.00\times10^6\text{ Pa}}\right)(3.00)(298.2\text{ K}) = 191\text{ K}$$

and (d) is the best choice.

6. From the ideal gas law, with the mass of the gas constant, $P_2V_2/T_2 = P_1V_1/T_1$. Thus,

$$P_2 = \left(\frac{V_1}{V_2}\right)\left(\frac{T_2}{T_1}\right)P_1 = \left(\frac{1}{2}\right)(4)P_1 = 2P_1$$

and (d) is the correct choice.

7. From the ideal gas law, with the mass of the gas constant, $P_2V_2/T_2 = P_1V_1/T_1$. Thus,

$$V_2 = \left(\frac{P_1}{P_2}\right)\left(\frac{T_2}{T_1}\right)V_1 = (4)(1)\left(0.50\ \text{m}^3\right) = 2.0\ \text{m}^3$$

and (c) is the correct choice.

8. The internal energy of *n* moles of a monatomic ideal gas is $U = \frac{3}{2}nRT$, where *R* is the universal gas constant and *T* is the absolute temperature of the gas. For the given neon sample,

$T = T_C + 273.15 = (152 + 273.15)\ \text{K} = 425\ \text{K}$, and

$$n = \frac{m}{molar\ mass} = \frac{26.0\ \text{g}}{20.18\ \text{g/mol}} = 1.29\ \text{mol}$$

Thus, $U = \frac{3}{2}(1.29\ \text{mol})(8.31\ \text{J/mol}\cdot\text{K})(425\ \text{K}) = 6.83\times10^3\ \text{J}$ and (b) is correct answer.

10. The kinetic theory of gases does assume that the molecules in a pure substance obey Newton's laws and undergo elastic collisions, and the average distance between molecules is very large in comparison to molecular sizes. However, it also assumes that the number of molecules in the sample is large so that statistical averages are meaningful. The untrue statement included in the list of choices is (a).

12. The rms speed of molecules in the gas is $v_{\text{rms}} = \sqrt{3RT/M}$. Thus, the ratio of the final speed to the original speed would be

$$\frac{(v_{\text{rms}})_f}{(v_{\text{rms}})_0} = \frac{\sqrt{3RT_f/M}}{\sqrt{3RT_0/M}} = \sqrt{\frac{T_f}{T_0}} = \sqrt{\frac{600\text{ K}}{200\text{ K}}} = \sqrt{3}$$

Therefore, the correct answer to this question is choice (d).

ANSWERS TO EVEN NUMBERED CONCEPTUAL QUESTIONS

2. The lower temperature will make the power line decrease in length. This increases the tension in the line so it is closer to the breaking point.

6. At high temperature and pressure, the steam inside exerts large forces on the pot and cover. Strong latches hold them together, but they would explode apart if you tried to open the hot cooker.

PROBLEM SOLUTIONS

10.1 (a) $T_F = \frac{9}{5}T_C + 32 = \frac{9}{5}(-273.15) + 32 = \boxed{-460°\text{F}}$

(b) $T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(98.6 - 32) = \boxed{37°\text{C}}$

(c) $T_F = \frac{9}{5}T_C + 32 = \frac{9}{5}(T_K - 273.15) + 32 = \frac{9}{5}(-173.15) + 32 = \boxed{-280°\text{F}}$

10.2 When the volume of a low-density gas is held constant, pressure and temperature are related by a linear equation $P = AT + B$, where A and B are constants to be determined. For the given constant-volume gas thermometer,

$$P = 0.700 \text{ atm when } T = 100°\text{C} \quad \Rightarrow \quad 0.700 \text{ atm} = A(100°\text{C}) + B \qquad \textbf{[1]}$$

$$P = 0.512 \text{ atm when } T = 0°\text{C} \quad \Rightarrow \quad 0.512 \text{ atm} = A(0) + B \qquad \textbf{[2]}$$

From Equation [2], $B = 0.512$ atm. Substituting this result into Equation [1] yields

$$A = \frac{0.700 \text{ atm} - 0.512 \text{ atm}}{100°\text{C}} = 1.88 \times 10^{-3} \text{ atm/°C}$$

so, the linear equation for this thermometer is: $P = \left(1.88 \times 10^{-3} \text{ atm/°C}\right)T + 0.512 \text{ atm}$

(a) If $P = 0.0400$ atm, then $T = \dfrac{P - B}{A} = \dfrac{0.0400 \text{ atm} - 0.512 \text{ atm}}{1.88 \times 10^{-3} \text{ atm/°C}} = \boxed{-251°\text{C}}$

(b) If $T = 450°\text{C}$, then $P = \left(1.88 \times 10^{-3} \text{ atm/°C}\right)(450°\text{C}) + 0.512 \text{ atm} = \boxed{1.36 \text{ atm}}$

10.5 Start with $T_F = -40°\text{F}$ and convert to Celsius.

$$T_C = \frac{5}{9}(T_F - 32) = \frac{5}{9}(-40 - 32) = \boxed{-40°\text{C}}$$

Since Celsius and Fahrenheit degrees of temperature change are different sizes (1 Celsius degree $= 1.8$ Fahrenheit degrees), this is the only temperature with the same numeric value on both scales.

10.11 The increase in temperature is $\Delta T = 35°\text{C} - (-20°\text{C}) = 55°\text{C}$.

Thus, $\Delta L = \alpha L_0 (\Delta T) = \left[11 \times 10^{-6}\ (°\text{C})^{-1}\right](518\text{ m})(55°\text{C}) = 0.31\text{ m} = \boxed{31\text{ cm}}$

10.14 (a) The diameter is a linear dimension, so we consider the linear expansion of steel:

$$d = d_0\left[1 + \alpha(\Delta T)\right] = (2.540\text{ cm})\left[1 + \left(11 \times 10^{-6}\ (°\text{C})^{-1}\right)(100.0°\text{C} - 25.00°\text{C})\right] = \boxed{2.542\text{ cm}}$$

(b) If the volume increases by 1.000%, then $\Delta V = \left(1.000 \times 10^{-2}\right)V_0$. Then, using $\Delta V = \beta V_0(\Delta T)$, where $\beta = 3\alpha$ is the volume expansion coefficient, we find

$$\Delta T = \frac{\Delta V / V_0}{\beta} = \frac{1.000 \times 10^{-2}}{3\left[11 \times 10^{-6}\ (°\text{C})^{-1}\right]} = \boxed{3.0 \times 10^2\ °\text{C}}$$

10.19 The difference in Celsius temperature in the underground tank and the tanker truck is

$$\Delta T_C = \frac{5}{9}(\Delta T_F) = \frac{5}{9}(95.0 - 52.0) = 23.9°\text{C}$$

If $V_{52°\text{F}}$ is the volume of gasoline that fills the tank at 52.0°F, the volume this quantity of gas would occupy on the tanker truck at 95.0°F is

$$V_{95°\text{F}} = V_{52°\text{F}} + \Delta V = V_{52°\text{F}} + \beta V_{52°\text{F}}(\Delta T) = V_{52°\text{F}}\left[1 + \beta(\Delta T)\right]$$
$$= \left(1.00 \times 10^3\text{ gal}\right)\left[1 + \left(9.6 \times 10^{-4}\ (°\text{C})^{-1}\right)(23.9°\text{C})\right] = \boxed{1.02 \times 10^3\text{ gal}}$$