Unit 5 – Thermal Properties

Boyle's Law

- $V \alpha 1/P$

Boyle's Law

- V α 1/P

$$\therefore \quad V_1P_1 = V_2P_2$$

Charle’s Law

- $V \quad \alpha \quad T$

Charle's Law

- V α T

$$\therefore \quad V_1 T_2 = V_2 T_1$$

Combined Gas Law

$$V_1 P_1 T_2 = V_2 P_2 T_1$$

A tire gauge reads 38.5 psi at 35.6°F. What will the gauge read at 115.0°F? (Assume constant volume.)

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$V_1 = \text{const.}$

$P_1 = 38.5 \text{ psi}$

$T_1 = 35.6 \text{ °F}$

$V_2 = \text{const.}$

$P_2 = ?$

$T_2 = 115.0 \text{ °F}$

$$\left(35.6°\cancel{F} - 32.0°\cancel{F}\right) \cdot \frac{1°C}{1.8°\cancel{F}} = 2.0°C$$

$$2.0°C + 273.15\ K = 275.2\ K$$

$$\left(115.0°\cancel{F} - 32.0°\cancel{F}\right) \cdot \frac{1°C}{1.8°\cancel{F}} = 46°C$$

$$46°C + 273.15\ K = 319\ K$$

A tire gauge reads 38.5 psi at 35.6°F. What will the gauge read at 115.0°F? (Assume constant volume.)

$$V_1 = \text{const.}$$

$$P_1 = 38.5 \text{ psi}$$

$$T_1 = 35.6\ ^\circ\text{F} = 275.2 \text{ K}$$

$$V_2 = \text{const.}$$

$$P_2 = ?$$

$$T_2 = 115.0\ ^\circ\text{F} = 319 \text{ K}$$

$$V_1 P_1 T_2 = V_2 P_2 T_1$$

$$P_1 T_2 = P_2 T_1$$

$$\therefore \; P_2 = \frac{P_1 T_2}{T_1} = \frac{(38.5\ \text{psi})(319\ \cancel{\text{K}})}{(275.2\ \cancel{\text{K}})}$$

$$\therefore \; P_2 = \boxed{44.6\ \text{psi}}$$

A 3.00 m^3 volume of air at 20.0°C and an atmospheric pressure of 16.8 psi is compressed to a volume of 0.750 m^3 at a gauge pressure of 149 psi. What is the temperature of the air in °C?

$$20.0°\text{C} + 273.15\ \text{K} = 293.2\ \text{K}$$

$$V_1P_1T_2 = V_2P_2T_1$$

$$\therefore\ T_2 = \frac{V_2P_2T_1}{V_1P_1} = \frac{\left(0.750\ \cancel{\text{m}^3}\right)\left(149\ \text{p}\cancel{\text{s}}\text{i}\right)\left(293.2\ \text{K}\right)}{\left(3.00\ \cancel{\text{m}^3}\right)\left(16.8\ \text{p}\cancel{\text{s}}\text{i}\right)}$$

$$\therefore\ T_2 = 65\bar{0}\ \text{K}$$

$$\therefore\ T_2 = 65\bar{0}\ \text{K} - 273.15\ \text{K} = \boxed{377°\text{C}}$$

357 L of argon gas is stored at a gauge pressure of 45.8 psi when the temperature is 12.9°C.

What is the new gauge pressure if the volume is compressed to 198 L and the temperature increases to 28.0°C?

$$12.9°C + 273.15\ K = 286.0\ K$$

$$28.0°C + 273.15\ K = 301.2\ K$$

$$V_1P_1T_2 = V_2P_2T_1$$

$$\therefore\ P_2 = \frac{V_1P_1T_2}{V_2T_1} = \frac{(357\ \cancel{L})(45.8\ \text{psi})(301.2\ \cancel{K})}{(198\ \cancel{L})(286.0\ \cancel{K})}$$

$$\therefore\ P_2 = \boxed{87.0\ \text{psi}}$$

A balloon is filled with 0.250 m^3 of helium when the temperature is 18.0°C? What is the volume of the balloon when the temperature is 38.0°C?

$$18.0°C + 273.15\ K = 291.2\ K$$

$$38.0°C + 273.15\ K = 311.2\ K$$

$$V_1 P_1 T_2 = V_2 P_2 T_1$$

$$\therefore \; V_2 = \frac{V_1 T_2}{T_1} = \frac{\left(0.250 \text{ m}^3\right)\left(311.2 \cancel{\text{K}}\right)}{\left(291.2 \cancel{\text{K}}\right)}$$

$$\therefore \; V_2 = \boxed{0.267 \text{ m}^3}$$

If 35.5 L of an ideal gas at atmospheric pressure is heated from 20.0°C to 98.0°C?

What is the new volume if the pressure triples?

$$20.0°C + 273.15\ K = 293.2\ K$$

$$98.0°C + 273.15\ K = 371.2\ K$$

$$V_1P_1T_2 = V_2P_2T_1$$

$$\therefore\ V_2 = \frac{V_1P_1T_2}{P_2T_1} = \frac{(35.5\ \text{L})(1.00\ \cancel{\text{atm}})(371.2\ \cancel{\text{K}})}{(3.00\ \cancel{\text{atm}})(293.2\ \cancel{\text{K}})}$$

$$\therefore\ V_2 = \boxed{15.0\ \text{L}}$$

An ideal gas at 20.0 °C and a pressure of 1.50×10^5 Pa is in a container having a volume of 1.00 L.

(a) Determine the number of moles of gas in the container. The gas pushes against a piston, expanding to twice its original volume, while the pressure falls to atmospheric pressure.

(b) Find the final temperature.

$$T = T_C + 273.15 = 20.0\ °\mathrm{C} + 273.15 = 293.2\ \mathrm{K}$$

$$PV = nRT$$

$$\therefore\ n = \frac{PV}{RT} = \frac{\left(1.50 \text{ x } 10^5\ \mathrm{kg/m\cdot s^2}\right)\left(1.00\ \mathrm{L}\cdot\frac{1 \text{ x } 10^{-3}\ \mathrm{m^3}}{1\ \mathrm{L}}\right)}{\left(8.31\ \mathrm{J/mol\cdot K}\right)\left(293.2\ \mathrm{K}\right)}$$

$$= \boxed{0.0616\ \mathrm{mol}}$$

$$\frac{P_f V_f}{P_i V_i} = \frac{nRT_f}{nRT_i} \qquad \therefore \quad \frac{P_f V_f}{P_i V_i} = \frac{T_f}{T_i}$$

$$\therefore \quad T_f = \frac{P_f V_f T_i}{P_i V_i} = \frac{\left(1.01 \text{ x } 10^5 \text{ Pa}\right)\left(2.00 \text{ L}\right)\left(293.2 \text{ K}\right)}{\left(1.50 \text{ x } 10^5 \text{ Pa}\right)\left(1.00 \text{ L}\right)}$$

$$= \boxed{395 \text{ K}}$$

A beachcomber finds a corked bottle containing a message. The air in the bottle is at atmospheric pressure and a temperature of 30.0 °C. The cork has a cross-sectional area of 2.30 cm^2. The beachcomber places the bottle over a fire, figuring the increased pressure will push out the cork. At a temperature of 99.0 °C the cork is ejected from the bottle.

(a) What was the pressure in the bottle just before the cork left it?
(b) What force of friction held the cork in place?
Neglect any change in volume of the bottle.

$$\frac{P_f V_f}{P_i V_i} = \frac{nRT_f}{nRT_i} \qquad \therefore \quad \frac{P_f}{P_i} = \frac{T_f}{T_i}$$

$$\therefore \quad P_f = \frac{P_i T_f}{T_i} = \frac{\left(1.01 \text{ x } 10^5 \text{ Pa}\right)\left(372.15 \text{ K}\right)}{\left(303.15 \text{ K}\right)}$$

$$= \boxed{1.24 \text{ x } 10^5 \text{ Pa}}$$

$$\Sigma F = 0 = \left(P_{\text{in}} A\right) - \left(P_{\text{out}} A\right) - \left(F_{\text{friction}}\right) = 0$$

$$\left(F_{\text{friction}}\right) = \left(P_{\text{in}} A\right) - \left(P_{\text{out}} A\right) = \left(P_{\text{in}} - P_{\text{out}}\right) A$$

$$= \left[\left(1.24 \text{ x } 10^5 \text{ Pa}\right) - \left(1.01 \text{ x } 10^5 \text{ Pa}\right)\right]\left(2.30 \text{ cm}^2 \cdot \frac{1 \text{ m}^2}{1 \text{ x } 10^4 \text{ cm}^2}\right)$$

$$= \boxed{5.29 \text{ N}}$$

300.0 L of argon gas is stored at a gauge pressure of 50.0 psi and a temperature of 14.00 °C.

(a) What is the new gauge pressure if the volume is compressed to 200.0 L and a temperature increases to 24.00 °C?

$$P_i V_i T_f = P_f V_f T_i$$

$$\therefore \quad P_f = \frac{P_i V_i T_f}{V_f T_i} = \frac{(50.0\ \text{psi})(300.0\ \text{L})(297.15\ \text{K})}{(200.0\ \text{L})(287.15\ \text{K})}$$

$$\therefore \quad P_f = \boxed{77.6\ \text{psi}}$$

A 3.00 m^3 volume of air at 20.00 °C and atmospheric pressure (14.7 psi) is compressed to a volume of 0.750 m^3 at a gauge pressure of 140.0 psi.

(a) What is the temperature of the air in °C?

$$P_i V_i T_f = P_f V_f T_i$$

$$\therefore \quad T_f = \frac{P_f V_f T_i}{P_i V_i} = \frac{(140.0 \text{ psi})(0.750 \text{ m}^3)(293.15 \text{ K})}{(14.7 \text{ psi})(3.00 \text{ m}^3)}$$

$$\therefore \quad T_f = 698 \text{ K} \qquad 698 \text{ K} - 273.15 = \boxed{425\ ^\circ\text{C}}$$