Act on Your Strategy
Pressure ratio:
P_1 = 10 000 kPa
P_2 = 100 kPa

pressure ratio > 1 is $\frac{10000 \text{ kPa}}{100 \text{ kPa}}$

Substitution to solve for V_2:

$$\begin{aligned} V_2 &= V_1 \times \text{pressure ratio} \\ &= 20 \text{ mL} \times \frac{10000 \ \cancel{\text{kPa}}}{100 \ \cancel{\text{kPa}}} \\ &= 2 \times 10^3 \text{ L} \end{aligned}$$

Number of balloons that can be filled:

$$\begin{aligned} \text{number of balloons} &= \frac{\text{total volume of helium}}{\text{volume of 1 balloon}} \\ &= \frac{2 \times 10^3 \ \cancel{\text{L}}}{2 \ \cancel{\text{L}}} \\ &= 1 \times 10^3 \end{aligned}$$

Therefore, 1×10^3, or 1000, balloons can be filled.

Check Your Solution
The initial pressure is greater than the final pressure and the initial volume is less than the final volume. This inverse relationship between volume and pressure is consistent with Boyle's law. The units are correct and the answer correctly shows one significant digit.

Section 11.3 Gases and Temperature Changes
Solutions for Practice Problems
Student Edition page 522

Note: Assume that the pressure and amount of gas are constant in all of the problems from question 11 to question 19.

11. Practice Problem (page 522)
A gas has a volume of 6.0 L at a temperature of 250 K. What volume will the gas have at 450K?

What Is Required?
You need to find the final volume, V_2, of the gas after it has been warmed to 450 K.

What Is Given?

You know the volume and temperature of the gas for the initial set of conditions and the temperature for the final set of conditions:

$V_1 = 6.0$ L
$T_1 = 250$ K
$T_2 = 450$ K

Plan Your Strategy

Temperature and volume are changing at constant pressure and amount of gas.

Use the equation for Charles's law: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Multiply each side of the equation by T_2 to isolate the variable V_2.

Substitute the numbers and units for the known variables in the formula and solve for V_2.

Act on Your Strategy

Isolation of the variable V_2:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{V_1}{T_1}(T_2) = \frac{V_2}{\cancel{T_2}}(\cancel{T_2})$$

$$V_2 = \frac{V_1 T_2}{T_1}$$

Substitution to solve for V_2:

$$\begin{aligned} V_2 &= \frac{V_1 T_2}{T_1} \\ &= \frac{(6.0\ \text{L})(450\ \cancel{\text{K}})}{250\ \cancel{\text{K}}} \\ &= 10.8\ \text{L} \\ &= 11\ \text{L} \end{aligned}$$

The final volume of the gas is 11 L.

Alternative Solution

Plan Your Strategy

According to Charles's law, an increase in Kelvin temperature will cause a directly proportional increase in volume. Therefore, the final volume will be greater than the initial volume.

Determine the ratio of the initial temperature and the final temperature that is greater than 1.
Multiply the initial volume by the temperature ratio determined to obtain the final volume.

Act on Your Strategy
Temperature ratio:
$T_1 = 250$ K
$T_2 = 450$ K
temperature ratio > 1 is $\frac{450\,\text{K}}{250\,\text{K}}$

Substitution to solve for V_2:

$$\begin{aligned}V_2 &= V_1 \times \text{ temperature ratio}\\ &= 6.0\text{ L} \times \frac{450\,\cancel{\text{K}}}{250\,\cancel{\text{K}}}\\ &= 10.8\text{ L}\\ &= 11\text{ L}\end{aligned}$$

The final volume of the gas is 11 L.

Check Your Solution
Charles's law predicts a direct relationship between the temperature in Kelvin and the volume. The Kelvin temperature increased by slightly less than 2 times. The volume also increased by slightly less than 2 times. The answer is reasonable and correctly shows two significant digits.

12. Practice Problem (page 522)
A syringe is filled with 30.0 mL of air at 298.15 K. If the temperature is raised to 353.25 K, what volume will the syringe indicate?

What Is Required?
You need to find the final volume, V_2, of air in a syringe after it has been warmed.

What Is Given?
You know the volume and temperature of the air for the initial set of conditions and the temperature for the final set of conditions:
$V_1 = 30.0$ mL
$T_1 = 298.15$ K
$T_2 = 353.25$ K

temperature ratio > 1 is $\frac{353.25\ \text{K}}{298.15\ \text{K}}$

Substitution to solve for V_2:

$$\begin{aligned} V_2 &= V_1 \times \text{temperature ratio} \\ &= 30.0\ \text{mL} \times \frac{353.25\ \cancel{\text{K}}}{298.15\ \cancel{\text{K}}} \\ &= 35.544\ \text{mL} \\ &= 35.5\ \text{mL} \end{aligned}$$

The syringe will indicate a final volume of 35.5 mL.

Check Your Solution
Volume units remain when the temperature units are cancelled out. From Charles's law, if the Kelvin temperature increases, the volume is expected to increase proportionally. The answer represents an increase in volume. The answer is reasonable and correctly shows three significant digits.

13. Practice Problem (page 522)
The temperature of a 2.25 L sample of gas decreases from 35.0°C to 20.0°C. What is the new volume?

What Is Required?
You need to find the final volume, V_2, of a sample of gas.

What Is Given?
You know the volume and temperature of the gas for the initial set of conditions and the temperature for the final set of conditions:
V_1 = 2.25 L
T_1 = 35.0°C
T_2 = 20.0°C

Plan Your Strategy
Temperature and volume are changing at constant pressure and amount of gas.
Use the equation for Charles's law: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$
Charles's law expresses a direct relationship between Kelvin temperature and volume. Convert the initial and final temperatures from degrees Celsius to kelvin units: K = °C + 273.15
Multiply each side of the equation by T_2 to isolate the variable V_2.
Substitute the numbers and units for the known variables in the formula and solve for V_2.

Act on Your Strategy
Temperature conversion:

$$\begin{aligned} T_1 &= 35°\text{C} + 273.15 \\ &= 308.15 \text{ K} \\ T_2 &= 20°\text{C} + 273.15 \\ &= 293.15 \text{ K} \end{aligned}$$

Isolation of the variable V_2:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{V_1}{T_1}(T_2) = \frac{V_2}{\cancel{T_2}}(\cancel{T_2})$$

$$V_2 = \frac{V_1 T_2}{T_1}$$

Substitution to solve for V_2:

$$\begin{aligned} V_2 &= \frac{V_1 T_2}{T_1} \\ &= \frac{2.25 \text{ L} \times 293.15 \cancel{\text{K}}}{308.15 \cancel{\text{K}}} \\ &= 2.14047 \text{ L} \\ &= 2.14 \text{ L} \end{aligned}$$

The new volume of the gas is 2.14 L.

Alternative Solution

Plan Your Strategy
According to Charles's law, a decrease in Kelvin temperature will cause a directly proportional decrease in volume. Therefore, the final volume will be less than the initial volume.
Determine the ratio of the initial temperature and the final temperature that is less than 1.
Multiply the initial volume by the temperature ratio determined to obtain the final volume.

Act on Your Strategy
Temperature ratio:
$T_1 = 308.15$ K
$T_2 = 293.15$ K

temperature ratio < 1 is $\dfrac{293.15\ \text{K}}{308.15\ \text{K}}$

Substitution to solve for V_2:

$$V_2 = V_1 \times \text{temperature ratio}$$
$$= 2.25\ \text{L} \times \frac{293.15\ \cancel{\text{K}}}{308.15\ \cancel{\text{K}}}$$
$$= 2.14047\ \text{L}$$
$$= 2.14\ \text{L}$$

The new volume of the gas is 2.14 L.

Check Your Solution

Volume units remain when the temperature units are cancelled out. From Charles's law, if the Kelvin temperature decreases, the volume is expected to decrease proportionally. The answer represents a smaller value for the volume. The answer is reasonable and correctly shows three significant digits.

14. Practice Problem (page 522)

A balloon is inflated with air in a room in which the air temperature is 27°C. When the balloon is placed in a freezer at −20.0°C, the volume is 80.0 L. What was the original volume of the balloon?

What Is Required?

You need to find the initial volume, V_1, of air in a balloon.

What Is Given?

You know the temperature of the air in the balloon for the initial set of conditions and the temperature and volume for the final set of conditions:

T_1 = 27°C

T_2 = –20.0°C

V_2 = 80.0 L

Plan Your Strategy

Temperature and volume are changing at constant pressure and amount of gas.

Use the equation for Charles's law: $\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$

Charles's law expresses a direct relationship between Kelvin temperature and volume. Convert the initial and final temperatures from degrees Celsius to kelvin units: K = °C + 273.15

Act on Your Strategy
Temperature ratio:
$T_1 = 300.15\ \text{K}$
$T_2 = 253.15\ \text{K}$
temperature ratio > 1 is $\dfrac{300.15\ \text{K}}{253.15\ \text{K}}$

Substitution to solve for V_1:

$$\begin{aligned} V_1 &= V_2 \times \text{temperature ratio} \\ &= 80.0\ \text{L} \times \frac{300.15\ \cancel{\text{K}}}{253.15\ \cancel{\text{K}}} \\ &= 94.852\ \text{L} \\ &= 95\ \text{L} \end{aligned}$$

The initial volume of air in the balloon was 95 L.

Check Your Solution
Volume units remain when the temperature units are cancelled out. From Charles's law, if the Kelvin temperature decreases, the volume is expected to decrease proportionally. The initial volume should be greater than the final volume when the temperature is decreased. The answer is reasonable and correctly shows two significant digits.

15. Practice Problem (page 522)
At a summer outdoor air temperature of 30.0°C, a particular size of bicycle tire has an interior volume of 685 cm^3. The bicycle has been left outside in the winter and the outdoor air temperature drops to –25.0°C. Assuming the tire had been filled with air in the summer, to what volume would the tire have been reduced at the winter air temperature?

What Is Required?
You need to find the final volume, V_2, of air in a bicycle tire.

What Is Given?
You know the volume and temperature of the air in the tire for the first set of conditions and the temperature for the second set of conditions:
$V_1 = 685\ \text{cm}^3$
$T_1 = 30.0°\text{C}$
$T_2 = –25.0°\text{C}$

Plan Your Strategy

Temperature and volume are changing at constant pressure and amount of gas.

Use the equation for Charles's law: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Charles's law expresses a direct relationship between Kelvin temperature and volume. Convert the initial and final temperatures from degrees Celsius to kelvin units: K = °C + 273.15

Multiply each side of the equation by T_2 to isolate the variable V_2.

Substitute the numbers and units for the known variables in the formula and solve for V_2.

Act on Your Strategy

Temperature conversion:

$$\begin{aligned} T_1 &= 30°\text{C} + 273.15 \\ &= 303.15 \text{ K} \\ T_2 &= –25.0°\text{C} + 273.15 \\ &= 248.15 \text{ K} \end{aligned}$$

Isolation of the variable V_2:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{V_1}{T_1}(T_2) = \frac{V_2}{\cancel{T_2}}(\cancel{T_2})$$

$$V_2 = \frac{V_1 T_2}{T_1}$$

Substitution to solve for V_2:

$$\begin{aligned} V_2 &= \frac{V_1 T_2}{T_1} \\ &= \frac{(685 \text{ cm}^3)(248.15 \cancel{\text{K}})}{303.15 \cancel{\text{K}}} \\ &= 560.721 \text{ cm}^3 \\ &= 561 \text{ cm}^3 \end{aligned}$$

The volume of air in the tire would have been reduced to 561 cm^3.

Alternative Solution

Plan Your Strategy
According to Charles's law, a decrease in Kelvin temperature will cause a directly proportional decrease in volume. Therefore, the final volume of air will be less than the initial volume. Determine the ratio of the initial temperature and the final temperature that is less than 1.
Multiply the initial volume by the temperature ratio determined to obtain the final volume.

Act on Your Strategy
Temperature ratio:
$T_1 = 303.15\text{ K}$
$T_2 = 248.15\text{ K}$
temperature ratio < 1 is $\dfrac{248.15\text{ K}}{303.15\text{ K}}$

Substitution to solve for V_2:

$$\begin{aligned} V_2 &= V_1 \times \text{temperature ratio} \\ &= 685\text{ cm}^3 \times \frac{248.15\ \cancel{\text{K}}}{303.15\ \cancel{\text{K}}} \\ &= 560.721\text{ cm}^3 \\ &= 561\text{ cm}^3 \end{aligned}$$

The volume of air in the tire would have been reduced to 561 cm^3.

Check Your Solution
Volume units remain when the temperature units are cancelled out. From Charles's law, if the Kelvin temperature decreases, the volume is expected to decrease proportionally. The answer represents a smaller value for the volume. The answer is reasonable and correctly shows three significant digits.

16. Practice Problem (page 522)
At 275 K, a gas has a volume of 25.5 mL. What is its temperature if the volume increases to 50.0 mL?

What Is Required?
You need to find the final Kelvin temperature, T_2, of a gas.

Alternative Solution

Plan Your Strategy

According to Charles's law, an increase in the Kelvin temperature will cause a directly proportional increase in the volume. Therefore, the final temperature will be greater than the initial temperature.

Determine the ratio of the initial volume and the final volume that is greater than 1.

Multiply the initial temperature by the volume ratio determined to obtain the final temperature.

Act on Your Strategy

Volume ratio:

$V_1 = 25.5$ mL

$V_2 = 50.0$ mL

volume ratio > 1 is $\dfrac{50.0 \text{ mL}}{25.5 \text{ mL}}$

Substitution to solve for T_2:

$$\begin{aligned} T_2 &= T_1 \times \text{ volume ratio} \\ &= 275 \text{ K} \times \frac{50.0 \cancel{\text{mL}}}{25.5 \cancel{\text{mL}}} \\ &= 539.215 \text{ K} \\ &= 539 \text{ K} \end{aligned}$$

The final temperature of the gas is 539 K.

Check Your Solution

From Charles's law, if the volume increases the Kelvin temperature must increase proportionally. The volume approximately doubles and the Kelvin temperature approximately doubles. The answer is reasonable and correctly shows three significant digits.

17. Practice Problem (page 522)

A sealed syringe contains 37.0 mL of trapped air. The temperature of the air in the syringe is

295 K. The sun shines on the syringe, causing the temperature of the air inside it to increase. If the volume increases to 38.6 mL, what is the new temperature of the air in the syringe?

What Is Required?

You need to find the final Kelvin temperature, T_2, of the air in the syringe.

What Is Given?
You know the volume and temperature of the air in the syringe for the first set of conditions and the volume for the second set of conditions:
$V_1 = 37.0$ mL
$T_1 = 295$ K
$V_2 = 38.6$ mL

Plan Your Strategy
Temperature and volume are changing at constant pressure and amount of gas.
Use the equation for Charles's law: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Multiply each side of the equation first by T_2 and then by $\frac{T_1}{V_1}$ to isolate the variable T_2.
Substitute the numbers and units for the known variables in the formula and solve for T_2.

Act on Your Strategy
Isolation of the variable T_2:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\left(\frac{V_1}{T_1}\right)(T_2) = \left(\frac{V_2}{\cancel{T_2}}\right)(\cancel{T_2})$$

$$\left(\frac{\cancel{V_1}}{\cancel{T_1}}\right)\left(\frac{\cancel{T_1}}{\cancel{V_1}}\right)(T_2) = (V_2)\left(\frac{T_1}{V_1}\right)$$

$$T_2 = \frac{V_2 T_1}{V_1}$$

Substitution to solve for T_2:

$$\begin{aligned} T_2 &= \frac{V_2 T_1}{V_1} \\ &= \frac{(38.6\ \cancel{\text{mL}})(295\ \text{K})}{37.0\ \cancel{\text{mL}}} \\ &= 307.756\ \text{K} \\ &= 308\ \text{K} \end{aligned}$$

The new temperature of the air in the syringe is 308 K.

Alternative Solution

Plan Your Strategy
According to Charles's law, an increase in volume will be caused by a directly proportional increase in the Kelvin temperature. Therefore, the final temperature will be greater than the initial temperature.
Determine the ratio of the initial volume and the final volume that is greater than 1.
Multiply the initial temperature by the volume ratio determined to obtain the final temperature.

Act on Your Strategy
Volume ratio:
V_1 = 37.0 mL
V_2 = 38.6 mL
volume ratio > 1 is $\frac{38.6 \text{ mL}}{37.0 \text{ mL}}$

Substitution to solve for T_2:

$$\begin{aligned} T_2 &= T_1 \times \text{ volume ratio} \\ &= 295 \text{ K} \times \frac{38.6 \cancel{\text{mL}}}{37.0 \cancel{\text{mL}}} \\ &= 307.756 \text{ K} \\ &= 308 \text{ K} \end{aligned}$$

The new temperature of the air in the syringe is 308 K.

Check Your Solution
From Charles's law, if the volume increases then the Kelvin temperature must increase proportionally. The final temperature is greater than the initial temperature. The answer is reasonable for the small increase in volume and correctly shows three significant digits.

18. Practice Problem (page 522)
A beach ball is inflated to a volume of 25 L of air in the cool of the morning at 15°C. During the afternoon, the volume changes to 26 L. What was the Celsius air temperature in the afternoon?

What Is Required?
You need to find the final Celsius temperature, T_2, of the gas.

Final temperature conversion:

$$T_2 = \text{K} - 273.15$$
$$= 299.676\ \text{K} - 273.15$$
$$= 26.526°\text{C}$$
$$= 27°\text{C}$$

The Celsius air temperature in the afternoon was 27°C.

Check Your Solution
From Charles's law, if the volume increases then the Kelvin temperature must increase proportionally. The final temperature is greater than the initial temperature. The answer is reasonable for the small increase in volume and correctly shows two significant digits.

19. Practice Problem (page 522)
The volume of a 1.50 L balloon at room temperature increases by 25.0 percent when placed in a hot-water bath. How does the temperature of the water bath compare with room temperature?

What Is Required?
You need to find the final temperature, T_2, of a water bath and compare it with the original room temperature.

What Is Given?
You know the volume and temperature of the air in the balloon for the first set of conditions and the volume for the second set of conditions:
$V_1 = 1.50$ L
$T_1 = T_1$ (room temperature)
$V_2 = 1.50$ L + 25% of 1.50 L

Plan Your Strategy
Determine the final volume, V_2.
Temperature and volume are changing at constant pressure and amount of gas.
Use the equation for Charles's law: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Multiply each side of the equation first by T_2 and then by $\frac{T_1}{V_1}$ to isolate the variable T_2.
Substitute the numbers and units for the known variables in the formula and solve for T_2.

Act on Your Strategy
Calculation of final volume:

$$\begin{aligned} V_2 &= 1.50 \text{ L} + (0.25)(1.50 \text{ L}) \\ &= 1.5 \text{ L} + 0.375 \text{ L} \\ &= 1.875 \text{ L} \end{aligned}$$

Isolation of the variable T_2:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\left(\frac{V_1}{T_1}\right)(T_2) = \left(\frac{V_2}{\cancel{T_2}}\right)(\cancel{T_2})$$

$$\left(\frac{\cancel{V_1}}{\cancel{T_1}}\right)\left(\frac{\cancel{T_1}}{\cancel{V_1}}\right)(T_2) = (V_2)\left(\frac{T_1}{V_1}\right)$$

$$T_2 = \frac{V_2 T_1}{V_1}$$

Substitution to solve for T_2:

$$\begin{aligned} T_2 &= \frac{V_2 T_1}{V_1} \\ &= \frac{1.875 \cancel{\text{L}} \times T_1}{1.50 \cancel{\text{L}}} \\ &= 1.25 T_1 \end{aligned}$$

The Kelvin temperature of the water bath is 1.25 times greater than the Kelvin temperature of the room.

Alternative Solution

Plan Your Strategy
According to Charles's law, an increase in volume will be caused by a directly proportional increase in the Kelvin temperature. Therefore, the final temperature (water bath) will be greater than the initial temperature (room). Determine the ratio of the initial volume and the final volume that is greater than 1.
Multiply the initial temperature by the volume ratio determined to obtain the final temperature.

Act on Your Strategy
Volume ratio:
$V_1 = 1.50\text{ L}$
$V_2 = 1.50\text{ L} + 25\%\text{ of }1.50\text{ L} = 1.875\text{ L}$

volume ratio > 1 is $\dfrac{1.875\text{ L}}{1.50\text{ L}}$

Substitution to solve for T_2:

$$\begin{aligned} T_2 &= T_1 \times \text{ volume ratio} \\ &= T_1 \times \frac{1.875\text{ L}}{1.50\text{ L}} \\ &= 1.25T_1 \end{aligned}$$

The Kelvin temperature of the water bath is 1.25 times greater than the Kelvin temperature of the room.

Check Your Solution
From Charles's law, if the volume increases then the Kelvin temperature must increase proportionally. The final temperature is greater than the initial temperature. The answer is reasonable and correctly shows three significant digits.

20. Practice Problem (page 522)

Compressed gases can be condensed when they are cooled. A 5.00×10^2 mL sample of carbon dioxide gas at room temperature (assume 25.0°C) is compressed by a factor of four, and then is cooled so that its volume is reduced to 25.0 mL. What must the final temperature be (in °C)?
(**Hint:** Use both Boyle's law and Charles's law to answer the question.)

What Is Required?
You must find the final temperature, in degrees Celsius, of a sample of gas that is first compressed and then cooled.

What Is Given?
You know the initial volume of the gas: $V_1 = 5.00 \times 10^2$ mL
You know the initial temperature of the gas: $T_1 = 25.0°\text{C}$
You know the final volume of the gas: $V_2 = 25.0$ mL
You know that the final pressure of the gas is 4 times the initial pressure:
$P_2 = 4P_1$