Unit 2 Forms of Matter: Gases
Solutions to Practice Problems

Unit 2 Preparation

1.
Problem
Lead has a density of 11.34 g/cm^3. What would be the mass of a block of lead if its volume was 225 cm^3?

What is Required?
You must calculate the mass of the lead given its density and volume.

What is Given?
density = D = 11.34 g/cm^3
volume = V = 225 cm^3

Plan Your Strategy
Use the formula for density and isolate the variable *m*. Multiply both sides of the equation by *V* to place it in the numerator, and isolate *m*. Substitute the numerical values for D and V into the equation and solve for m. Determine the number of significant digits and round the final answer.

Act on Your Strategy

$$DV = \left(\frac{m}{\cancel{V}}\right)\cancel{V}$$

$$DV = m$$

$$m = (11.34\, g/cm^3)(225\, cm^3)$$

$$m = 2551.5 g$$

$$m \approx 2.55 \times 10^3 g$$

Solution
The mass of the block of lead is 2.55×10^3 g.

Check Your Solution
The units cancelled to give grams, which is correct. The number of significant digits (3) is correct.

2.
Problem
The gas pressure in a nitrogen tank is 4.1×10^4 kPa. The nitrogen exerts a force of 4.5×10^7 N on the base of the tank. What is the area of the base of the tank?

What is Required?
You need to calculate the area of the base of the tank.

What is Given?
Simplify the units by converting kilopascals to kN/m^2, and by dividing newtons by 1000 to get kilonewtons.

$$\text{pressure} = P = 4.1 \times 10^4 \, kPa = 4.1 \times 10^4 \, \frac{kN}{m^2}$$

$$\text{force} = F = 4.5 \times 10^7 \, N = 4.5 \times 10^4 \, kN$$

Plan Your Strategy
Use the formula for pressure and isolate the variable *A*. Multiply both sides of the equation by *A* to place *A* in the numerator. Now you must divide both sides of the equation by *P* to isolate *A*. Substitute the numerical values into the equation and solve for *A*. Determine the number of significant digits and round the final answer.

Act on Your Strategy

$$P = \frac{F}{A}$$

$$PA = \left(\frac{F}{\cancel{A}}\right)\cancel{A}$$

$$\frac{\cancel{P}A}{\cancel{P}} = \frac{F}{P}$$

$$A = \frac{F}{P}$$

$$A = \frac{4.5 \times 10^4 \, \cancel{kN}}{4.1 \times 10^4 \, \frac{\cancel{kN}}{m^2}}$$

$$A = 1.097 \, m^2$$

$$A \approx 1.1 \, m^2$$

Solution
The area of the base of the tank is 1.1 m^2.

Check Your Solution
The units cancelled correctly to give the area in m^2. The value calculated was slightly greater than 1, which you would expect when dividing approximately 40 000 by approximately 40 000.

3.
Problem
Water is poured into a graduated cylinder. If the pressure on the bottom of the cylinder, due to the water, is 3.25 kPa and the cross sectional area of the bottom of the cylinder is 53 cm^2, what is the weight of the water? (Remember that weight is the force that an object exerts on the surface that is supporting it.)

What is Required?
You need to find the weight, in newtons or kilonewtons, of the water in the cylinder.

What is Given?
Simplify the units by converting kilopascals to kN/m^2, and dividing cm^2 by 100 to get m^2.
pressure = P = 3.25 kPa = 3.25 $\frac{kN}{m^2}$
area of the base of the cylinder = A = 53 cm^2 = 0.53 m^2

Plan Your Strategy
Rearrange the formula for pressure to solve for *F* by multiplying both sides by *A*. Substitute the known values into the equation and solve it.

Act on Your Strategy

$$P = \frac{F}{A}$$

$$PA = \left(\frac{F}{\cancel{A}}\right)\cancel{A}$$

$$F = PA$$

$$F = (3.25\frac{kN}{m^2})(0.35\,m^2)$$

$$F = 1.7225\ kN$$

$$F \approx 1.7\,kN\ or\ F \approx 1700\,N$$

Solution
The weight of the water in the cylinder is 1.7 kN.

Check Your Solution
The units cancelled correctly to give a weight in kilonewtons, and the solution has the correct number of significant digits (2).

4.
Problem
Helium has a density of 0.179 g/L under conditions of standard temperature and pressure. What would be the volume of a sample of helium that has the same mass as the block of lead in question 1? (**Hint:** 1 L = 1000 cm^3)

What is Required?
Find the volume of a sample of helium.

What is Given?
Simplify the units by converting the density, in g/L, to g/1000 cm^3.
density = D = 0.179 g/L = 0.179 g/1000 cm^3
mass = m = 2.55×10^3 g (calculated in Question 1.)

Plan Your Strategy
Rearrange the equation for density to isolate for *V*. Multiply both sides of the equation by *V* to place it in the numerator. Now you must divide both sides of the equation by *D*. Substitute the numerical values into the equation and solve for *V*.

Act on Your Strategy

$$D = \frac{m}{V}$$

$$DV = \left(\frac{m}{\cancel{V}}\right)\cancel{V}$$

$$DV = m$$

$$\frac{\cancel{D}V}{\cancel{D}} = \frac{m}{D}$$

$$V = \frac{m}{D}$$

$$V = \frac{2.55 \times 10^{3}\ \cancel{g}}{\frac{0.179\ \cancel{g}}{1000\,cm^{3}}}$$

$$V = 1.42 \times 10^{7}\ cm^{3}\ or$$

$$V = 1.42 \times 10^{5}\ m^{3}$$

Solution
The volume of the helium sample would be 1.42×10^{7} cm^3.

Check Your Solution
The units cancelled to give cubic centimetres, which is correct. The number of significant digits (3) is also correct.

5.
Problem
You need to add 2.75 moles of potassium carbonate (K_2CO_3) to a quantity of water to make a solution. What will be the mass of the potassium carbonate?

What is Required?
You must find the mass, *m*, of 2.75 mol of potassium carbonate.

What is Given?
The formula for potassium carbonate is K_2CO_3.
number of moles = n = 2.75 mol

Plan Your Strategy

Find the molar masses of K, C, and O from a periodic table. Then determine the mass of one formula unit of K_2CO_3. Input this mass, *M*, and the number of moles, *n*, into the formula for number of moles and solve for the mass, *m*.

Act on Your Strategy
Molar mass:
K: 39.10 g/mol
C: 12.01 g/mol
O: 16.00 g/mol

K_2CO_3: 2(39.10 g/mol) + 12.01 g/mol + 3(16.00 g/mol) = 138.21 g/mol

$$n = \frac{m}{M}$$

$$n\mathrm{M} = \left(\frac{m}{\cancel{M}}\right)\cancel{M}$$

$$m = nM$$

m = (2.75 mol)(138.21 g/mol)
m = 380 g

Solution
The mass of 2.75 mol of potassium carbonate is 380 g.

Check Your Solution
The unit of mass is grams, and the units cancelled correctly to give grams.

6.
Problem
You have determined that there are 4.005×10^{-4} mol of a gas in a container. The mass of the gas is 16.00 mg. What is the molar mass of the gas?

What is Required?
You must find the molar mass of a gas.

What is Given?
Simplify the units by converting the mass in milligrams to grams by dividing by 1000.
number of moles = $n = 4.005 \times 10^{-4}$ mol
mass = m = 16.00 mg = 0.01600 g

Plan Your Strategy
Rearrange the formula for number of moles to solve for *M* by multiplying both sides of the equation by *M* and dividing both sides by *n*.

Act on Your Strategy

$$n = \frac{m}{M}$$

$$nM = \left(\frac{m}{\cancel{M}}\right)\cancel{M}$$

$$\frac{\cancel{n}M}{\cancel{n}} = \frac{m}{n}$$

$$M = \frac{m}{n}$$

$$M = \frac{0.01600\,g}{4.005 \times 10^{-4}\,mol}$$

$$M = 39.95\frac{g}{mol}$$

Solution
The molar mass of the gas is 39.95 g/mol.

Check Your Solution
The units correctly cancelled to give a molar mass in grams per mole, which is correct. The number of significant digits (4) is also correct.

Chapter 3 Properties of Gases

1.
Problem
A sample of gas in a flexible container has a volume of 6.9 L after its pressure has been increased from 1.0 atm to 3.5 atm. What was the initial volume of the gas?

What is Required?
You must calculate the initial volume, V_1, of a sample of gas before the pressure was increased.

What is Given?
initial pressure = P_1 = 1 atm
final pressure = P_2 = 3.5 atm
final volume V_2 = 6.9 L
The temperature is constant.

Plan Your Strategy
Since the temperature remains constant, and the pressure and volume of gas are known, Boyle's law can be used to solve for the initial volume, V_1.

Act on Your Strategy
Applying Boyle's law:
$P_1V_1 = P_2V_2$

$$V_1 = \frac{P_2V_2}{P_1} = \frac{3.5\,\text{atm} \times 6.9\,\text{L}}{1\,\text{atm}} = 24\text{ L}$$

Check Your Solution
The final volume, after the pressure was increased, is smaller than the initial volume. The answer is reasonable, has the correct units (L), and has the correct number of significant digits (2).

2.
Problem
A flexible container holding 3.50 L of hydrogen gas at standard atmospheric pressure has to be compressed into a volume of 1.75 L. If there is no change in temperature, what pressure is required?

What is Required?
You must calculate the final pressure, P_2, on a sample of gas to cause the volume decrease.

What is Given?
initial pressure = P_1 = standard pressure = 101.325 kPa
initial volume V_1 = 3.50 L
final volume V_2 = 1.75 L
The temperature is constant.

Plan Your Strategy
Since the temperature remains constant, and the pressure and volume of gas are known, Boyle's law can be used to solve for the final pressure, P_2.

Act on Your Strategy
Applying Boyle's law:
$P_1V_1 = P_2V_2$

$$P_2 = \frac{P_1V_1}{V_2} = \frac{101.325\,\text{kPa} \times 3.50\,\text{L}}{1.75\,\text{L}} = 203\text{ kPa}$$

Check Your Solution
The final pressure is larger than the initial pressure, and the volume decreased. The answer is reasonable, has the correct units (kPa), and has the correct number of significant digits (3).

3.
Problem
A sample of neon gas at room temperature is collected in a 2.50 L balloon at standard atmospheric pressure. The balloon is then submerged into a tub of water, also at room temperature, so that the external pressure is increased to 112.5 kPa. What will be the final volume of the balloon?

What is Required?
You must calculate the final volume of a balloon, V_2, after an increase in pressure.

What is Given?
initial pressure = P_1 = standard pressure = 101.325 kPa
final pressure = P_2 = 112.5 kPa
initial volume V_1 = 2.50 L
The temperature is constant.

Plan Your Strategy
Since the temperature remains constant, and pressure and volume of gas are known, Boyle's law can be used to solve for the final volume, V_2.

Act on Your Strategy
Applying Boyle's law:

$$P_1V_1 = P_2V_2$$

$$V_2 = \frac{P_1V_1}{P_2} = \frac{101.325\ \text{kPa} \times 2.50\ \text{L}}{112.5\ \text{kPa}} = 2.25\ \text{L}$$

Check Your Solution
The final volume is smaller than the initial volume after the pressure was increased. The answer is reasonable, has the correct units (L), and has the correct number of significant digits (3).

4.
Problem
A flexible container holds 4.0 L of air at 22 ^{o}C. If the temperature of the air remains constant, what will be the volume of the air if the pressure doubles?

What is Required?
You must calculate the final volume of a sample of gas, V_2, after the pressure doubles.

What is Given?
initial pressure = P_1
final pressure = P_2 = 2 × P_1
initial volume V_1 = 4.0 L
The temperature is constant.

Plan Your Strategy
Since the temperature remains constant, and the pressure and volume of gas are known, Boyle's law can be used to solve for the final volume, V_2.

Act on Your Strategy
Applying Boyle's law:

$$P_1V_1 = P_2V_2$$

$$V_2 = \frac{P_1V_1}{P_2} = \frac{P_1 \times 4.0\,\text{L}}{2P_1} = 2.0\ \text{L}$$

Check Your Solution
The final volume, after the pressure was doubled, is half of the initial volume. The answer is reasonable, has the correct units (L), and has the correct number of significant digits (2).

5.
Problem
The volume of gas in a 25 mL syringe attached to a pressure gauge is 2.50 mL when the pressure gauge reads 8.26 bar. If there has been no change in temperature when the plunger of the syringe is pulled back to allow the gas to occupy 20.0 mL, what does the pressure gauge read?

What is Required?
You must calculate the final pressure, P_2, on a sample of gas after the volume increased.

What is Given?
initial pressure = P_1 = 8.26 bar
initial volume V_1 = 2.50 mL
final volume V_2 = 20.0 mL
The temperature is constant.

Plan Your Strategy
Since the temperature remains constant, and the pressure and volume of gas are known, Boyle's law can be used to solve for the final pressure, P_2.

Act on Your Strategy
Applying Boyle's law:
$P_1V_1 = P_2V_2$

$$P_2 = \frac{P_1V_1}{V_2} = \frac{8.26\,\text{bar} \times 2.50\,\text{L}}{20.0\,\text{L}} = 1.03\ \text{bar}$$

Check Your Solution
The final pressure is smaller than the initial pressure, which is consistent with the increase in the gas's volume.. The answer is reasonable, has the correct units (bar), and has the correct number of significant digits (3).

6.
Problem
A 2.5 L container is filled with helium gas at a pressure of 3.5 atm. If the temperature remains constant, what volume would this gas occupy at 98 kPa?

What is Required?
You must calculate the final volume of a balloon, V_2, after an increase in pressure.

What is Given?
initial pressure = P_1 = 3.5 atm
final pressure = P_2 = 98 kPa
initial volume V_1 = 2.5 L
The temperature is constant.

Plan Your Strategy
Since the two pressures are not in the same unit, one pressure unit must be converted to the other. Change 3.5 atm pressure to kilopascals using the conversion factor 1.0 atm = 101.325 kPa. Since the temperature remains constant, and pressure and volume of gas are known, Boyle's law can be used to solve for the final volume, V_2.

Act on Your Strategy

$$V_1 = 3.5 \text{ atm} \times \frac{101.325\,\text{kPa}}{1.0\,\text{atm}} = 354.6375 \text{ kPa}$$

Applying Boyle's law:

$$P_1V_1 = P_2V_2$$

$$V_2 = \frac{P_1V_1}{P_2} = \frac{354.6375 \text{ kPa} \times 2.5\,\text{L}}{98\,\text{kPa}} = 9.0 \text{ L}$$

Check Your Solution
The final volume, after the pressure was decreased, is larger than the initial volume. The answer is reasonable, has the correct units (L), and has the correct number of significant digits (2).

7. a)
Problem
Convert 27.3 ^{o}C to the Kelvin scale.

What is Required?
You must convert a Celsius temperature to the equivalent Kelvin temperature.

What is Given?
The Celsius temperature, t, is 27.3 ^{o}C.

Plan Your Strategy
The conversion factor between the Celsius and Kelvin scales is
T (Kelvin) = t(Celsius) + 273.15

Act on Your Strategy
T = 27.3 °C + 273.15 = 300.4 K

Check Your Solution
The answer has the correct units (K) and the correct number of significant digits (4).

7. b)
Problem
Convert 37.8 °C to the Kelvin scale.

What is Required?
You must convert a Celsius temperature to the equivalent Kelvin temperature.

What is Given?
The Celsius temperature, t, is 37.8 °C.

Plan Your Strategy
The conversion factor between the Celsius and Kelvin scales is
T (Kelvin) = t(Celsius) + 273.15

Act on Your Strategy
T = 37.8 °C + 273.15 = 311.0 K

Check Your Solution
The answer has the correct units (K) and the correct number of significant digits (4).

7. c)
Problem
Convert 122.4 °C to the Kelvin scale.

What is Required?
You must convert a Celsius temperature to the equivalent Kelvin temperature.

What is Given?
The Celsius temperature, t, is 122.4 °C.

Plan Your Strategy
The conversion factor between the Celsius and Kelvin scales is
T (Kelvin) = t(Celsius) + 273.15

Act on Your Strategy
T = 122.4°C + 273.15 = 395.6 K

Check Your Solution
The answer has the correct units (K) and the correct number of significant digits (4).

7. d)
Problem
Convert –25 ^oC to the Kelvin scale.

What is Required?
You must convert a Celsius temperature to the equivalent Kelvin temperature.

What is Given?
The Celsius temperature, *t*, is –25 ^oC.

Plan Your Strategy
The conversion factor between the Celsius and Kelvin scales is
T (Kelvin) = t(Celsius) + 273.15

Act on Your Strategy
$T = -25\ ^oC + 273.15 = 248\ K$

Check Your Solution
The answer has the correct units (K) and the correct number of significant digits (3).

7. e)
Problem
Convert –40 ^oC to the Kelvin scale.

What is Required?
You must convert a Celsius temperature to the equivalent Kelvin temperature.

What is Given?
The Celsius temperature, *t*, is –40 ^oC.

Plan Your Strategy
The conversion factor between the Celsius and Kelvin scales is
T (Kelvin) = t(Celsius) + 273.15

Act on Your Strategy
$T = -40\ ^oC + 273.15 = 233\ K$

Check Your Solution
The answer has the correct units (K) and the correct number of significant digits (3).

8. a)
Problem
Convert 373.2 K to Celsius.
You must convert a Kelvin temperature to the equivalent Celsius temperature.

What is Given?
The Kelvin temperature, *T*, is 373.2 K.

Plan Your Strategy
The conversion factor between the Kelvin and Celsius scales is
t(Celsius) = T (Kelvin) – 273.15

Act on Your Strategy
t = 373.2 K – 273.15 = 100.0 ^{o}C

Check Your Solution
The answer has the correct units (^{o}C) and the correct number of significant digits (4).

8. b)
Problem
Convert 275 K to Celsius.
You must convert a Kelvin temperature to the equivalent Celsius temperature.

What is Given?
The Kelvin temperature, *T*, is 275 K.

Plan Your Strategy
The conversion factor between the Kelvin and Celsius scales is
t(Celsius) = T (Kelvin) – 273.15

Act on Your Strategy
t = 275 K – 273.15 = 2 ^{o}C

Check Your Solution
The answer has the correct units (^{o}C) and the correct number of significant digits (1).

8. c)
Problem
Convert 173 K to Celsius.
You must convert a Kelvin temperature to the equivalent Celsius temperature.

What is Given?
The Kelvin temperature, *T*, is 173 K.

Plan Your Strategy
The conversion factor between the Kelvin and Celsius scales is
t(Celsius) = T (Kelvin) – 273.15

Act on Your Strategy
t = 173 K – 273.15 = –100 ^{o}C

Check Your Solution
The answer has the correct units (^{o}C) and the correct number of significant digits (3).

8. d)
Problem
Convert 23.5 K to Celsius.
You must convert a Kelvin temperature to the equivalent Celsius temperature.

What is Given?
The Kelvin temperature, *T*, is 23.5 K.

Plan Your Strategy
The conversion factor between the Kelvin and Celsius scales is
t(Celsius) = *T* (Kelvin) – 273.15

Act on Your Strategy
t = 23.5 K – 273.15 = –249.6 ^{o}C

Check Your Solution
The answer has the correct units (^{o}C) and the correct number of significant digits (4).

8. e)
Problem
Convert 873 K to Celsius.

What is Required?
You must convert a Kelvin temperature to the equivalent Celsius temperature.

What is Given?
The Kelvin temperature, *T*, is 873 K.

Plan Your Strategy
The conversion factor between the Kelvin and Celsius scales is
t(Celsius) = *T* (Kelvin) – 273.15

Act on Your Strategy
t = 873 K – 273.15 = 600 ^{o}C

Check Your Solution
The answer has the correct units (^{o}C) and the correct number of significant digits (3).

9.
Problem
A 75 mL balloon immersed in liquid nitrogen at –196 ^{o}C is lifted out and left in a room at 22.3 ^{o}C. What is the final volume of the balloon?

What is Required?
You must calculate the final volume, V_2, of a balloon after the temperature is increased.

What is Given?
initial volume = V_1 = 75 mL
initial temperature = t_1 = – 196 ^{o}C
final temperature = t_2 = 22.3 ^{o}C

Plan Your Strategy
Convert the Celsius temperature to Kelvin using the relationship
T (Kelvin) = t(Celsius) + 273.15
Since the pressure is constant, and the volume and temperature are known, Charles's law can be used.

Act on Your Strategy
T (Kelvin) = t(Celsius) + 273.15

T_1 = –196 ^{o}C + 273.15 = 77.15 K
T_2 = 22.3 ^{o}C + 273.15 = 295.45 K
Apply Charles's law

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

$$V_2 = \frac{V_1 T_2}{T_1} = \frac{75\,\text{mL} \times 295.45\,\text{K}}{77.15\,\text{K}} = 2.9 \times 10^2 \text{ mL or } 0.29 \text{ L}$$

Check Your Solution
The final volume, after the temperature increased, is greater than the initial volume. The answer is reasonable, has the correct units (L), and has the correct number of significant digits (2).

10.
Problem
A child's balloon is filled to a volume of 3.0 L with room temperature air (22 ºC). The balloon will burst if it reaches a volume of 3.5 L. The child takes the balloon with her in the car when she goes shopping with her mother on a hot day. They leave the balloon in the closed car while they are shopping. The temperature of the air in the car reached a temperature of 38 ºC. Did the balloon burst? Support your answer with calculations.

What is Required?
You need to find the final volume, V_2, of the balloon and compare it with the volume at which the balloon will burst.

What is Given?
initial volume = V_1 = 3.0 L
initial temperature = t_1 = 22 ºC
final temperature = t_2 = 38 ºC

You know that the balloon will burst if it reaches a volume of 3.5 L.

Plan Your Strategy
Use Charles's law to calculate the second volume, V_2. To isolate V_2, you need to multiply both sides of the equation by T_2. Convert the Celsius temperature to Kelvin using the relationship
T (Kelvin) = t(Celsius) + 273.15

Act on Your Strategy
$T1$ = 22 ºC + 273.15 = 295.15 K
$T2$ = 38 ºC + 273.15 = 311.15 K

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

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

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

$$V_2 = \frac{(3.0\,L)(311.15\,K)}{295.15\,K}$$

$$V_2 = 3.2\,L$$

Solution
Since the final volume of the balloon was 3.2 L, and the balloon will not burst until it reaches a volume of 3.5 L, the balloon did not burst in the hot car.

Check Your Solution
The units for the answer are volume units, and volume units remain in the solution when the other units cancel out.

11.
Problem
A sealed syringe contains 37.0 mL of trapped air. The temperature of the air in the syringe is the same as room temperature or 295 K. The Sun shines on the syringe causing the temperature of the air inside 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 must find the final temperature, T_2, of the air in the syringe.

What is Given?
initial volume = V_1 = 37.0 mL
final volume = V_2 = 38.6 mL
initial temperature = T_1 = 295 K

Plan Your Strategy
Use Charles's law to solve for the second temperature, T_2. Multiply both sides of the equation by $T2$ to bring it into the numerator. Divide both sides of the equation by $\frac{V_1}{T_1}$, or multiply by its reciprocal, $\frac{T_1}{V_1}$, to isolate T_2. Substitute in the numerical values for the variables, and solve.

Act on Your Strategy

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

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

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

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

$$T_2 = \frac{(38.6\,mL)(295\,K)}{37.0\,mL}$$

$$T_2 = 308\,K$$

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

Check Your Solution
The units correctly cancel out to give an answer in Kelvin, which is appropriate for a temperature measurement. The results showed an increase in temperature as expected.

12.
Problem
The volume of a 1.5 L balloon at room temperature increases by 25% of its volume when it is placed in a hot-water bath. How does the temperature of the water bath compare with room temperature?

What is Required?
You must calculate the final temperature, T_2, of a water bath knowing that the change in temperature causes the volume of a balloon to increase.

What is Given?
initial volume = V_1 = 1.5 L
final volume = V_2 = 1.25% × V_1
initial temperature = T_1
The pressure is constant.

Plan Your Strategy
Since the pressure is constant, and the relationship between the initial and final temperature is known, use Charles's law to solve for the relationship between the initial room temperature and the final temperature, T_2.

Act on Your Strategy
$V_2 = 1.25 \times V_1$
Apply Charles's law
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$T_2 = \frac{V_2 T_1}{V_1} = \frac{1.25 V_1}{V_1} = 1.25\ T_1$$
Alternatively, since $T \propto V$, $T_2 = 1.25\ T_1$
The Kelvin temperature increases by 25%, or by a factor of 1.25.

Check Your Solution
The final Kelvin temperature is greater than the initial Kelvin temperature and is proportional to the increase in volume. This is not true of the Celsius temperature. For example, if the Celsius room temperature was 22.0 ºC, the temperature of the water bath would be 95.6 ºC.

13.
Problem
A birthday balloon is filled with a 1.80 L of helium gas at 20.0 ^{o}C. The balloon expands to a volume of 5.40 L. If the pressure remains constant, what is the final Celsius temperature of the gas in the balloon?

What is Required?
You must calculate the final Celsius temperature, t_2, after a temperature change that causes an increase in the volume of a balloon.

What is Given?
initial volume = V_1 = 1.80 L
final volume = V_2 = 5.40 L
initial temperature = t_1 = 20.0 ^{o}C

Plan Your Strategy
Convert the Celsius temperature to Kelvin using the relationship
T (Kelvin) = t(Celsius) + 273.15
Since the pressure remains constant and the volume and temperature are known, Charles's law can be used to calculate the final temperature. Convert this temperature back to Celsius using the relationship
t(Celsius) = T(Kelvin) – 273.15

Act on Your Strategy
T (Kelvin) = t(Celsius) + 273.15
T_1 = 20.0 °C + 273.15 = 293.15 K
V_1 = 1.80 L
V_2 = 5.40 L
Apply Charles's law

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

$$T_2 = \frac{V_2 T_1}{V_1} = \frac{5.40\,\text{L} \times 293.15\,\text{K}}{1.80\,\text{L}} = 879.45\ \text{K}$$

t(Celsius) = T(Kelvin) – 273.15
= 879.45 – 273.15 = 606 °C

Check Your Solution
The final temperature is greater than the initial temperature, and it resulted in an increase in the volume of the balloon. The answer is reasonable, has the correct units (°C), and has the correct number of significant digits (3).

14.
Problem
Compressed gases can be condensed when they are cooled. A 500 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:** Try using both Boyle's law and Charles's law to answer the question.)

What is Required?
You must calculate the final temperature of a sample of gas that has first been compressed and then had its temperature reduced.

What is Given?
initial volume = V_1 = 500 mL
initial temperature = T_1 = 25.0 °C
initial pressure = P_1
final pressure = 4 × P_1

Plan Your Strategy
Step 1. Assume that the temperature is constant and apply Boyle's law to determine the effect on the volume of increasing the pressure by a factor of 4.
Step 2. Convert the Celsius temperature to Kelvin using the relationship
T (Kelvin) = t(Celsius) + 273.15
Use the final volume from Step 1 as the initial volume for Step 2. Assume that the pressure is constant and apply Charles's law to determine the effect of decreasing the temperature.

Act on Your Strategy
Apply Boyle's law to find the final volume of the gas after it has been compressed.

$P_1V_1 = P_2V_2$

$$V_2 = \frac{P_1V_1}{P_2} = \frac{P_1 \times 500\,\text{mL}}{4P_1} = 125 \text{ mL}$$

This final volume then becomes the initial volume used in Charles's law to find the final temperature.

T (Kelvin) = t(Celsius) + 273.15

T_1 = 25.0 °C + 273.15 = 298.15 K

V_1 = 125 mL

V_2 = 25.0 mL

Apply Charles's law

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

$$T_2 = \frac{V_2T_1}{V_1} = \frac{25\,\text{mL} \times 298.15\,\text{K}}{125\,\text{mL}} = 59.63 \text{ K}$$

t(Celsius) = T(Kelvin) – 273.15

= 59.63 – 273.15 = –214 °C

Check Your Solution

The final temperature is lower than the initial temperature, and it resulted in a decrease in the volume of the gas. The answer is reasonable, has the correct units (°C), and has the correct number of significant digits (3).