Key

Boyles' Law $P_1V_1 = P_2V_2$

Use Boyles' Law to answer the following questions:

1) 1.00 L of a gas at standard temperature and pressure is compressed to 473 mL. What is the new pressure of the gas?

$P_1 = 1 atm$
$V_1 = 1L = 1000 mL$
$P_2 = ?$
$V_2 = 473 mL$

$(1 atm)(1000 mL) = P_2 (473 mL)$

$\frac{(1 atm)(1000 mL)}{473 mL} = P_2$

$P_2 = 2.11 atm$

2) In a thermonuclear device, the pressure of 0.050 liters of gas within the bomb casing reaches 4.0×10^6 atm. When the bomb casing is destroyed by the explosion, the gas is released into the atmosphere where it reaches a pressure of 1.00 atm. What is the volume of the gas after the explosion?

$P_1 = 4000000 atm$
$V_1 = 0.05 L$
$P_2 = 1.0 atm$
$V_2 = ?$

$(4000000 atm)(0.05 L) = (1 atm) V_2$

$\frac{(4000000 atm)(0.05 L)}{(1 atm)} = V_2$

$V_2 = 200{,}000 L$

3) Synthetic diamonds can be manufactured at pressures of 6.00×10^4 atm. If we took 2.00 liters of gas at 1.00 atm and compressed it to a pressure of 6.00×10^4 atm, what would the volume of that gas be?

$P_1 = 1 atm$
$V_1 = 2L$
$P_2 = 60000 atm$
$V_2 = ?$

$(1 atm)(2L) = (60000 atm) V_2$

$\frac{(1 atm)(2L)}{(60000 atm)} = V_2$

$V_2 = 333{,}000 L$

4) The highest pressure ever produced in a laboratory setting was about 2.0×10^6 atm. If we have a 1.0×10^{-5} liter sample of a gas at that pressure, then release the pressure until it is equal to 0.275 atm, what would the new volume of that gas be?

$P_1 = 2000000 atm$
$V_1 = .00001 L$
$P_2 = 0.275 atm$
$V_2 = ?$

$(2000000 atm)(0.00001 L) = (0.275 atm) V_2$

$\frac{(2000000 atm)(0.00001 L)}{0.275 atm} = V_2$

$V_2 = 72.7 L$

5) Atmospheric pressure on the peak of Mt. Everest can be as low as 150 mm Hg, which is why climbers need to bring oxygen tanks for the last part of the climb. If the climbers carry 10.0 liter tanks with an internal gas pressure of 3.04×10^4 mm Hg, what will be the volume of the gas when it is released from the tanks?

$P_1 = 30400$ mmHg
$V_1 = 10$ L
$P_2 = 150$ mmHg
$V_2 = ?$

$(30400 \text{ mmHg})(10 \text{ L}) = (150 \text{ mmHg}) V_2$

$\frac{(30400 \text{ mmHg})(10 \text{ L})}{150 \text{ mmHg}} = V_2$

$V_2 = 2000$ L

6) Part of the reason that conventional explosives cause so much damage is that their detonation produces a strong shock wave that can knock things down. While using explosives to knock down a building, the shock wave can be so strong that 12 liters of gas will reach a pressure of 3.8×10^4 mm Hg. When the shock wave passes and the gas returns to a pressure of 760 mm Hg, what will the volume of that gas be?

$P_1 = 38000$ mmHg
$V_1 = 12$ L
$P_2 = 760$ mmHg
$V_2 = ?$

$(38000 \text{ mmHg})(12 \text{ L}) = (760 \text{ mmHg}) V_2$

$\frac{(38000 \text{ mmHg})(12 \text{ L})}{760 \text{ mmHg}} = V_2$

$V_2 = 600$ L

7) Submarines need to be extremely strong to withstand the extremely high pressure of water pushing down on them. An experimental research submarine with a volume of 15,000 liters has an internal pressure of 1.2 atm. If the pressure of the ocean breaks the submarine forming a bubble with a pressure of 250 atm pushing on it, how big will that bubble be?

$P_1 = 1.2$ atm
$V_1 = 15{,}000$ L
$P_2 = 250$ atm
$V_2 = ?$

$(1.2 \text{ atm})(15{,}000 \text{ L}) = (250 \text{ atm}) V_2$

$\frac{(1.2 \text{ atm})(15{,}000 \text{ L})}{250 \text{ atm}} = V_2$

$V_2 = 72$ L

8) Divers get "the bends" if they come up too fast because gas in their blood expands, forming bubbles in their blood. If a diver has 0.05 L of gas in his blood under a pressure of 250 atm, then rises instantaneously to a depth where his blood has a pressure of 50.0 atm, what will the volume of gas in his blood be? Do you think this will harm the diver?

$P_1 = 250$ atm
$V_1 = 0.05$ L
$P_2 = 50.0$ atm
$V_2 = ?$

$(250 \text{ atm})(0.05 \text{ L}) = (50 \text{ atm}) V_2$

$\frac{(250 \text{ atm})(0.05 \text{ L})}{50 \text{ atm}} = V_2$

$V_2 = 0.25$ L, yes

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

Charles' Law Worksheet

1) The temperature inside my refrigerator is about 4^0 Celsius. If I place a balloon in my fridge that initially has a temperature of 22^0 C and a volume of 0.5 liters, what will be the volume of the balloon when it is fully cooled by my refrigerator?

$V_1 = ?$

$T_1 = 4°C = 277K$

$V_2 = 0.5L$

$T_2 = 22°C = 295K$

$$\frac{V_1}{277K} = \frac{0.5L}{295K}$$

$$V_1 = \frac{0.5L}{295K} \cdot 277K$$

$$\boxed{V_1 = 0.47L}$$

2) A man heats a balloon in the oven. If the balloon initially has a volume of 0.4 liters and a temperature of 20 ^{0}C, what will the volume of the balloon be after he heats it to a temperature of 250 ^{0}C?

$V_1 = 0.4L$

$T_1 = 20°C = 293K$

$V_2 = ?$

$T_2 = 250°C = 523K$

$$\frac{0.4L}{293K} = \frac{V_2}{523K}$$

$$\frac{0.4L}{293K} \cdot 523K = V_2$$

$$\boxed{V_2 = 0.71L}$$

3) On hot days, you may have noticed that potato chip bags seem to "inflate", even though they have not been opened. If I have a 250 mL bag at a temperature of 19 ^{0}C, and I leave it in my car which has a temperature of 60^0 C, what will the new volume of the bag be?

$V_1 = 250mL$

$T_1 = 19°C = 292K$

$V_2 = ?$

$T_2 = 60°C = 333K$

$$\frac{250mL}{292K} = \frac{V_2}{333K}$$

$$\frac{250mL}{292K} \cdot 333K = V_2$$

$$\boxed{V_2 = 285mL}$$

4) A soda bottle is flexible enough that the volume of the bottle can change even without opening it. If you have an empty soda bottle (volume of 2 L) at room temperature (25 ^{0}C), what will the new volume be if you put it in your freezer (-4 ^{0}C)?

$V_1 = 2L$

$T_1 = 25°C = 298K$

$V_2 = ?$

$T_2 = -4°C = 269K$

$$\frac{2L}{298K} = \frac{V_2}{269K}$$

$$\frac{2L}{298K} \cdot 269K = V_2$$

$$\boxed{V_2 = 1.81L}$$

5) Some students believe that teachers are full of hot air. If I inhale 2.2 liters of gas at a temperature of 18^0 C and it heats to a temperature of 38^0 C in my lungs, what is the new volume of the gas?

$V_1 = 2.2L$

$T_1 = 18°C = 291K$

$V_2 = ?$

$T_2 = 38°C = 311K$

$$\frac{2.2L}{291K} = \frac{V_2}{311K}$$

$$\frac{2.2L}{291K} \cdot 311K = V_2$$

$$V_2 = 2.35L$$

6) How hot will a 2.3 L balloon have to get to expand to a volume of 400 L? Assume that the initial temperature of the balloon is 25 ^{0}C.

$V_1 = 2.3L$

$T_1 = 25°C = 298K$

$V_2 = 400L$

$T_2 = ?$

$$\frac{2.3L}{298K} = \frac{400L}{T_2}$$

$$\frac{2.3L}{298K} \cdot T_2 = 400L$$

$$T_2 = 400L \cdot \frac{298K}{2.3L}$$

$$T_2 = 51,800K$$

7) I have made a thermometer which measures temperature by the compressing and expanding of gas in a piston. I have measured that at 100^0 C the volume of the piston is 20 L. What is the temperature outside if the piston has a volume of 15 L? What would be appropriate clothing for the weather?

$V_1 = 20L$

$T_1 = 100°C = 373K$

$V_2 = 15L$

$T_2 = ?$

$$\frac{20L}{373K} = \frac{15L}{T_2}$$

$$\frac{20L}{373K} \cdot T_2 = 15L$$

$$20L \cdot T_2 = 15L \cdot 373K$$

$$T_2 = 15L \cdot \frac{373K}{20L}$$

$$T_2 = 298.5K = 25°C$$

Combined Gas Law Problems

Use the combined gas law to solve the following problems:

1) If I initially have a gas at a pressure of 12 atm, a volume of 23 liters, and a temperature of 200 K, and then I raise the pressure to 14 atm and increase the temperature to 300 K, what is the new volume of the gas?

$P_1 = 12 atm$, $V_1 = 23 L$, $T_1 = 200 K$, $P_2 = 14 atm$, $V_2 = ?$, $T_2 = 300 K$

$$\frac{(12 atm)(23 L)}{200 K} = \frac{(14 atm) V_2}{300 K}$$

$$\frac{(12 atm)(23 L)}{200 K} \cdot \frac{300 K}{14 atm} = V_2$$

$V_2 = 29.6 L$

2) A gas takes up a volume of 17 liters, has a pressure of 2.3 atm, and a temperature of 299 K. If I raise the temperature to 350 K and lower the pressure to 1.5 atm, what is the new volume of the gas?

$P_1 = 2.3 atm$, $V_1 = 17 L$, $T_1 = 299 K$, $P_2 = 1.5 atm$, $T_2 = 350 K$, $V_2 = ?$

$$\frac{(2.3 atm)(17 L)}{299 K} = \frac{(1.5 atm) V_2}{350 K}$$

$$\frac{(2.3 atm)(17 L)}{299 K} \cdot \frac{350 K}{1.5 atm} = V_2$$

$V_2 = 30.5 L$

3) A gas that has a volume of 28 liters, a temperature of 45 ^{0}C, and an unknown pressure has its volume increased to 34 liters and its temperature decreased to 35 ^{0}C. If I measure the pressure after the change to be 2.0 atm, what was the original pressure of the gas?

$P_1 = ?$, $V_1 = 28 L$, $T_1 = 45°C = 318 K$, $P_2 = 2.0 atm$, $V_2 = 34 L$, $T_2 = 35°C = 308 K$

$$\frac{P_1 (28 L)}{318 K} = \frac{(2.0 atm)(34 L)}{308 K}$$

$$P_1 = \frac{318 K}{28 L} \cdot \frac{(2.0 atm)(34 L)}{308 K}$$

$P_1 = 2.51 atm$

4) A gas has a temperature of 14 ^{0}C, and a volume of 4.5 liters. If the temperature is raised to 29 ^{0}C and the pressure is not changed, what is the new volume of the gas?

~~P_1~~, $V_1 = 4.5 L$, $T_1 = 14°C = 287 K$, ~~P_2~~, $V_2 = ?$, $T_2 = 29°C = 302 K$

$$\frac{4.5 L}{287 K} = \frac{V_2}{302 K}$$

$$\frac{4.5 L}{287 K} \cdot 302 K = V_2$$

$4.74 L = V_2$

5) If I have 17 liters of gas at a temperature of 67 ^{0}C and a pressure of 88.89 atm, what will be the pressure of the gas if I raise the temperature to 94 ^{0}C and decrease the volume to 12 liters?

$P_1 = 88.89\,atm$
$V_1 = 17L$
$T_1 = 67°C = 340K$
$P_2 = ?$
$T_2 = 94°C = 367K$
$V_2 = 12L$

$$\frac{(88.89\,atm)(17L)}{340K} = \frac{P_2(12L)}{367K}$$

$$\frac{(88.89\,atm)(17L)}{340K} \cdot \frac{367K}{12L} = P_2$$

$P_2 = 136\,atm$

6) I have an unknown volume of gas at a pressure of 0.5 atm and a temperature of 325 K. If I raise the pressure to 1.2 atm, decrease the temperature to 320 K, and measure the final volume to be 48 liters, what was the initial volume of the gas?

$P_1 = 0.5\,atm$
$V_1 = ?$
$T_1 = 325K$
$P_2 = 1.2\,atm$
$V_2 = 48L$
$T_2 = 320K$

$$\frac{(0.5\,atm)V_1}{325K} = \frac{(1.2\,atm)(48L)}{320K}$$

$$V_1 = \frac{325K}{0.5L} \cdot \frac{(1.2\,atm)(48L)}{320K}$$

$V_1 = 117L$

7) If I have 21 liters of gas held at a pressure of 78 atm and a temperature of 900 K, what will be the volume of the gas if I decrease the pressure to 45 atm and decrease the temperature to 750 K?

$P_1 = 78\,atm$
$V_1 = 21L$
$T_1 = 900K$
$P_2 = 45\,atm$
$V_2 = ?$
$T_2 = 750K$

$$\frac{(78\,atm)(21L)}{900K} = \frac{(45\,atm)V_2}{750K}$$

$$\frac{(78\,atm)(21L)}{900K} \cdot \frac{750K}{45\,atm} = V_2$$

$V_2 = 30.3L$

8) If I have 2.9 L of gas at a pressure of 5 atm and a temperature of 50 ^{0}C, what will be the temperature of the gas if I decrease the volume of the gas to 2.4 L and decrease the pressure to 3 atm?

$P_1 = 5\,atm$
$V_1 = 2.9L$
$T_1 = 50°C = 323K$
$P_2 = 3\,atm$
$V_2 = 2.4L$
$T_2 = ?$

$$\frac{(5\,atm)(2.9L)}{323K} = \frac{(3\,atm)(2.4L)}{T_2}$$

$$\frac{(5\,atm)(2.9L)}{323K} \cdot T_2 = (3\,atm)(2.4L)$$

$$T_2 = (3\,atm)(2.4L)\frac{(323K)}{(5\,atm)(2.9L)}$$

$T_2 = 160K$

9) I have an unknown volume of gas held at a temperature of 115 K in a container with a pressure of 60 atm. If by increasing the temperature to 225 K and decreasing the pressure to 30 atm causes the volume of the gas to be 29 liters, how many liters of gas did I start with?

$P_1 = 60\,atm$
$V_1 = ?$
$T_1 = 115K$
$P_2 = 30\,atm$
$V_2 = 29L$
$T_2 = 225K$

$$\frac{(60\,atm)V_1}{115K} = \frac{(30\,atm)(29L)}{225K}$$

$$V_1 = \frac{115K}{60\,atm} \cdot \frac{(30\,atm)(29L)}{225K}$$

$V_1 = 7.41L$