Section 11.8: The Gas Laws—Absolute Temperature and Charles' Law

Tutorial 1 Practice, page 549

1. (a) Given: $t = -78$ °C
Required: T
Analysis: $T = t + 273$
Solution:
$T = -78 + 273$
$T = 195$ K
Statement: Dry ice sublimes into a gas at 195 K.
(b) Given: $t = 45$ °C
Required: T
Analysis: $T = t + 273$
Solution:
$T = 45 + 273$
$T = 318$ K
Statement: The hottest temperature recorded in Canada is 318 K.
2. (a) Given: $T = 1337$ K
Required: t
Analysis:

$$T = t + 273$$
$$t = T - 273$$

Solution:
$t = 1337 - 273$
$t = 1046$ °C
Statement: Pure gold melts at 1046 °C.
(b) Given: $T = 210$ K
Required: t
Analysis:

$$T = t + 273$$
$$t = T - 273$$

Solution:
$t = 210 - 273$
$t = -63$ °C
Statement: The coldest temperature recorded in Canada is –63 °C.

Mini Investigation: Soap in the Microwave, page 551

Answers may vary. Sample answers:
A. Ivory soap expanded much more than the other soap during heating. This is because it contained more air and water.
B. Ivory soap will soften during heating. The air contained in the Ivory soap will expand when heated. Water in this soap can become a vapour during heating. The water vapour will occupy more space that the trapped water. These expanding gases will push on the soap to expand its shape.
C. Charles' Law states that if all other factors are constant, the volume of a gas is directly proportional to temperature. In the case of the Ivory soap, we see that as the temperature of the gas increases, the volume also increases.

Research This: Evaluating the Use of Nitrogen in Car Tires, page 551

Answers may vary. Sample answers:

A. Tires that are underinflated may not be able to maintain their shape. This has the effect of changing the type of contact that the tire has with the road. A change in contact can lead to both tire failure and reduced life of the tire treads. Tires that are overinflated may also have reduced contact with the road. Overinflation can increase the damage that occurs to tires with encountering rough road or debris. Both underinflated and overinflated tires are more easily damaged than tires that are properly inflated.

B. Underinflated tires can reduce your gas mileage. Higher tire pressure will reduce rolling resistance which can increase gas mileage, but exceeding manufacturer's limits is dangerous. Keeping your tires at the manufacturer's suggested pressure is the best way to ensure safety and good gas mileage.

C. Nitrogen has a more consistent rate of expansion and contraction when compared to air. Differences in track and tire temperatures over the course of a race will produce less volume changes in tires filled with nitrogen compared to tires filled with air. There is also less water vapour in nitrogen compared to air. On race day, tires filled with nitrogen are less affected by humidity. Tires filled with nitrogen will have less expansion due to less water vapour.

D. Answers may vary. Sample answer: Tires filled with nitrogen typically show little performance gains over tires filled with regular air. Most tests have shown a negligible benefit over air filled tires on gas mileage and only a slight benefit over air filled tires on retaining pressure. A bigger factor in car performance is having your tires regularly checked.

Tutorial 2 Practice, page 552

1. Given: initial Kelvin temperature, t_1 = 200 K
final Kelvin temperature, t_2 = 300 K
volume, V_1 = 5.25 L
The amount of the gas and the gas pressure remain constant.
Required: final volume, V_2
Analysis: Apply Charles' law to the situation.

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

Solution:
Step 1. Rearrange the Charles' law equation to isolate the unknown variable.

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

Step 2. Substitute given values (including units) into the equations and solve.

$$V_2 = \frac{5.25\ \text{L} \times 300\ \cancel{\text{K}}}{200\ \cancel{\text{K}}}$$

$$V_2 = 7.88\ \text{L}$$

Statement: The volume of the gas at 300 K is 7.88 L.

2. Given: initial Celsius temperature, $t_1 = 35$ °C
initial volume, $V_1 = 2.2$ L
final volume, $V_2 = 4.4$ L
The amount of the gas and the gas pressure remain constant.
Required: final Kelvin temperature, T_2

Analysis: Apply Charles' law to the situation.

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

Solution:
Step 1. Convert temperature values to kelvins.

$$T = t + 273$$

$$\begin{aligned} T_1 &= t_1 + 273 \\ &= 35 + 273 \\ T_1 &= 308 \end{aligned}$$

Step 2. Rearrange the Charles' law equation to isolate the unknown variable.

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

Step 3. Substitute given values (including units) into the equations and solve.

$$T_2 = \frac{308\ \text{K} \times 4.4\ \cancel{\text{L}}}{2.2\ \cancel{\text{L}}}$$

$$T_2 = 620\ \text{K}$$

Statement: The temperature at which the gas occupies 4.4 L is 620 K.

Section 11.8 Questions, page 553

1. As matter is cooled to absolute zero the entities move slower and slower. Theoretically, at absolute zero there should be no motion and therefore no kinetic energy.
2. (a) Given: $T = 1700$ K
Required: t
Analysis: $T = t + 273$

$$t = T - 273$$

Solution:
$t = 1700 - 273$
$t = 1427$ °C
Statement: The flame from a match can have temperatures in the range of 1427 °C.
(b) Given: $t = 2327$ °C
Required: T
Analysis: $T = t + 273$
Solution:
$T = 2327 + 273$
$T = 2600$ K
Statement: The tungsten filament can reach over 2600 K.

(c) Given: t = –268 °C
Required: T
Analysis: $T = t + 273$
Solution:
T = –268 + 273
T = 5 K
Statement: Helium becomes a liquid below 5 K.
(d) Given: T = 54 K
Required: t
Analysis: $T = t + 273$

$$t = T - 273$$

Solution:
t = 54 – 273
t = –219 °C
Statement: Oxygen was first made into a solid at a temperature near –219 °C.
3. Given: initial Celsius temperature, t_1 = 22 °C
final Kelvin temperature, t_2 = 77 K
initial volume, V_1 = 0.57 L
The amount of the gas and the gas pressure remain constant.
Required: final volume, V_2
Analysis: Apply Charles' law to the situation.

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

Solution:
Step 1. Convert temperature values to kelvins.

$$T = t + 273$$

$$\begin{aligned} T_1 &= t_1 + 273 \\ &= 22 + 273 \\ T_1 &= 295 \text{ K} \end{aligned}$$

Step 2. Rearrange the Charles' law equation to isolate the unknown variable.

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

Step 3. Substitute given values (including units) into the equations and solve.

$$V_2 = \frac{0.57 \text{ L} \times 77 \not{\text{K}}}{295 \not{\text{K}}}$$

$$V_2 = 0.15 \text{ L}$$

Statement: The volume of the balloon at 77 K is 0.15 L.

Copyright © 2011 Nelson Education Ltd.

4. Given: initial Celsius temperature, t_1 = 50.0 °C
initial volume, V_1 = 0.300 L
The final temperature, t_2, is the standard ambient temperature, which is 25 °C.
The amount of the gas and the gas pressure remain constant.
Required: final volume, V_2
Analysis: Apply Charles' law to the situation.

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

Solution:
Step 1. Convert temperature values to kelvins.

$$T = t + 273$$

$$\begin{aligned} T_1 &= t_1 + 273 \\ &= 50 + 273 \\ T_1 &= 323 \text{ K} \end{aligned}$$

$$\begin{aligned} T_2 &= t_2 + 273 \\ &= 25 + 273 \\ T_2 &= 298 \text{ K} \end{aligned}$$

Step 2. Rearrange the Charles' law equation to isolate the unknown variable.

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

Step 3. Substitute given values (including units) into the equations and solve.

$$V_2 = \frac{0.300 \text{ L} \times 298 \not{\text{K}}}{323 \not{\text{K}}}$$

$$V_2 = 0.277 \text{ L}$$

Statement: The volume of the sample of gas at 25 °C is 0.277 L.
5. Given: initial Celsius temperature, t_1 = –20.0 °C
final Celsius temperature, t_2 = –110 °C
initial volume, V_1 = 25 cm^3
The amount of the gas and the gas pressure remain constant.
Required: final volume, V_2
Analysis: Apply Charles' law to the situation.

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

Solution:
Step 1. Convert temperature values to kelvins.
$$T = t + 273$$

$$\begin{aligned} T_1 &= t_1 + 273 \\ &= -20 + 273 \\ T_1 &= 253 \text{ K} \end{aligned}$$

$$\begin{aligned} T_2 &= t_2 + 273 \\ &= -110 + 273 \\ T_2 &= 163 \text{ K} \end{aligned}$$

Step 2. Rearrange the Charles' law equation to isolate the unknown variable.
$$V_2 = \frac{V_1 T_2}{T_1}$$
Step 3. Substitute given values (including units) into the equations and solve.
$$V_2 = \frac{25 \ \cancel{\text{cm}^3} \times 163 \ \cancel{\text{K}}}{253 \ \cancel{\text{K}}} \times \frac{1 \text{ L}}{1000 \ \cancel{\text{cm}^3}}$$
$$V_2 = 0.016 \text{ L}$$
Statement: The volume of the gas just before it sublimes will be 0.016 L.
6. Given: initial Celsius temperature, t_1 = 1170 °C
final Celsius temperature, t_2 = 120 °C
initial volume, V_1 = 0.45 L
The amount of the gas and the gas pressure remain constant.
Required: final volume, V_2
Analysis: Apply Charles' law to the situation.
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$
Solution:
Step 1. Convert temperature values to kelvins.
$$T = t + 273$$

$$\begin{aligned} T_1 &= t_1 + 273 \\ &= 1170 + 273 \\ T_1 &= 1443 \text{ K} \end{aligned}$$

$$\begin{aligned} T_2 &= t_2 + 273 \\ &= 120 + 273 \\ T_2 &= 393 \text{ K} \end{aligned}$$

Step 2. Rearrange the Charles' law equation to isolate the unknown variable.

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

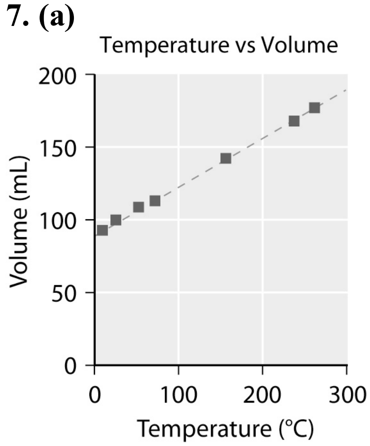
Step 3. Substitute given values (including units) into the equations and solve.

$$V_2 = \frac{0.45\ \text{L} \times 393\ \cancel{\text{K}}}{1443\ \cancel{\text{K}}}$$

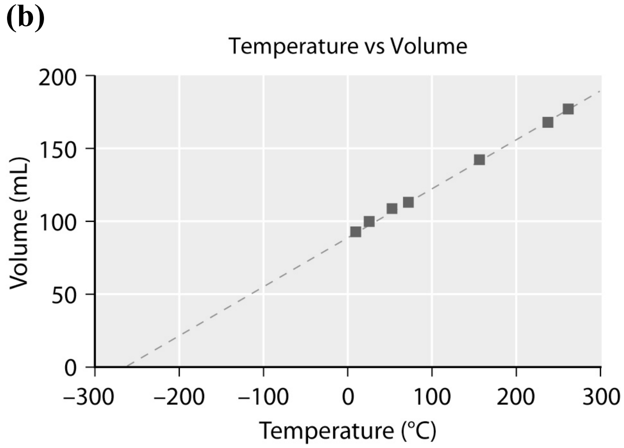
$$V_2 = 0.12\ \text{L}$$

Statement: The volume of the water vapour at 120 °C is 0.12 L.

7. (a)



(b)



The experimental value of absolute zero is –275 K.

(c) Answers may vary. Sample answer: The value determined by the experiment is quite close to the theoretical value. Limitations of the apparatus used to measure temperature and/or volume may cause the difference. There also may be effects from atmospheric pressure.

8. Answers may vary. Sample answer: An upper limit for temperature is the subject of debate. There are several proposals for the upper limit of temperature, and they are all dependent on the type of modelling used to calculate these values. The Standard Model suggests there is an upper limit to temperature of 10^{23} K. This is known as the Planck temperature after German physicist Max Plank. The enormity of this number is difficult to comprehend when we consider that the temperature of the core of the Sun is around 10^7 K. Physicists who use string theory have proposed the upper limit of temperature at 2×10^{30} K. This is referred to as the Hagedorn temperature. Other estimations exist and depend on the model used to calculate these values.

9. Flights of the Montgolfier brothers used hot air generated by an iron stove. The fuel was damp straw and wool. The brothers thought they had discovered a new gas which they called Montgolfier gas. In fact it was just hot smoky air. The hot air is less dense that the surrounding air. The hot air rises and causes the balloon to rise.

10. The Valsalva manoeuvre is performed by closing the mouth, pinching your nose, and trying to forcefully exhale. A clicking or popping sound is often heard during this process. It is used to equalize pressure in the ears and sinuses when there are changes in atmospheric pressure (e.g., when diving underwater or in a plane at high altitude). Changes in pressure can be painful in the ears and sinuses. This technique allows air into the Eustachian tube to equalize pressure in the middle ear with outside pressure to relieve the pain.

11. Participants in extreme diving descend with a single breath and without the use of supplementary oxygen. At 10 m below the surface, the diver's lung capacity is reduced by one half and this reduces to one quarter at a depth of 30 m. At a depth of 100 m, the lung capacity is reduced to the size of "two oranges." At great depths very little oxygen can reach the bloodstream. This can result in participants blacking out. Other hazards include ruptured ear drums and damage to limbs because of the extreme pressure. The "rapture of the deep", the loss of feeling and movement at great depths, can result from the pressure from water which can compress lungs, blood vessels, and decrease heart beat. Extreme divers also experience a build up of carbon dioxide in their blood. Divers must overcome the body's reflex to breathe.

Copyright © 2011 Nelson Education Ltd.