

5 Absolute Zero Kelvin Scale



Think About It

The coldest temperature recorded on Earth was in Antarctica: a chilling $-89\text{ }^{\circ}\text{C}$. The temperature is even lower on other planets that are farther away from the Sun. Researchers have recorded temperatures as low as $-235\text{ }^{\circ}\text{C}$ on the surface of Triton, a moon of Neptune!

How cold can substances become?

To answer this question, you will explore

- 1 Absolute Zero
- 2 Kelvin Scale
- 3 Molecules in Motion

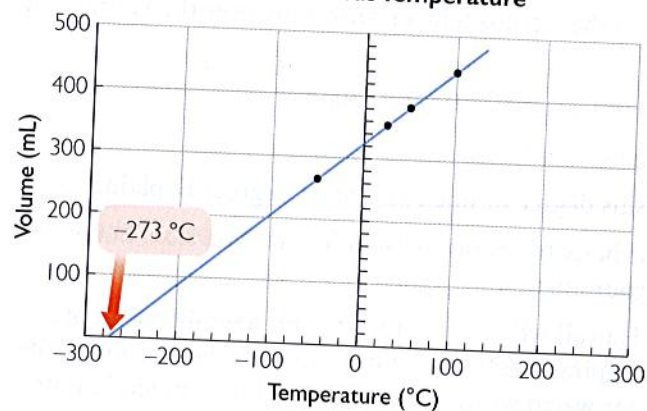
Exploring the Topic

1 Absolute Zero

The volumes of most substances decrease as the temperature decreases. But there is a limit to how much a substance can shrink. It does not make sense that matter would have a negative volume. Hypothetically, the lowest temperature possible would correspond to a volume of zero.

Consider an example. The volume of a gas inside a flexible container is measured as the gas is cooled. Several data points are then plotted on a graph.

Volume Versus Temperature



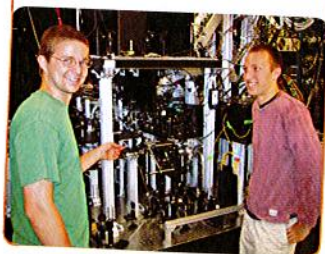
Using the Graph

This graph shows that as the temperature decreases, the volume decreases in a predictable way. The data points collected lie more or less on a straight line. If you extend this line to the x-axis, you can determine the theoretical temperature of the gas at zero volume.

More precise measurements reveal $-273.15\text{ }^{\circ}\text{C}$ as the temperature at zero volume. Scientists hypothesize that this value corresponds to the lowest temperature possible, and call it **absolute zero**. In actuality, as the temperature is lowered a gas would condense to a liquid and then to a solid well above this temperature, so zero volume is a hypothetical point. No one has ever caused a substance to reach absolute zero, but scientists have come very close—within a small fraction of a degree.

HISTORY CONNECTION

In 2003, researchers at the Massachusetts Institute of Technology cooled a sample of sodium gas to 5000 picokelvins, or 0.0000000005 kelvin. This is the coldest temperature ever recorded in a laboratory.



2 Kelvin Scale

On the Celsius scale the temperature at which the volume of gas is theoretically zero is $-273\text{ }^{\circ}\text{C}$. If you want to create a scale where the temperature is 0 when the volume is 0, you must add 273 to each temperature. This new temperature scale is called the **Kelvin scale**. One kelvin is the same size as one Celsius degree.

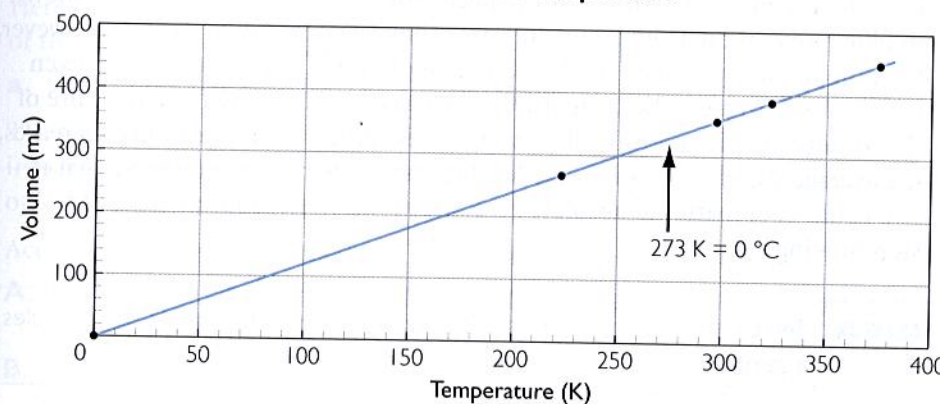
$$K = C + 273$$

$$C = K - 273$$

For example, to convert $20\text{ }^{\circ}\text{C}$ to kelvins, add 273. This temperature corresponds to 293 K.

Note that the word degree, or the symbol for degree, $^{\circ}$, is not used with the Kelvin scale. The unit of temperature on the Kelvin scale is the kelvin, K.

Volume Versus Temperature

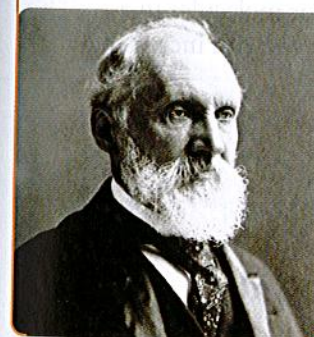


Using the Graph

The Kelvin scale sets the zero point at absolute zero. As a result, all temperatures are positive when they are expressed in kelvins. Notice that this graph is the same as the previous graph, but the x-axis has been shifted by 273. The value for $0\text{ }^{\circ}\text{C}$ is 273 K.

HISTORY CONNECTION

The Kelvin temperature scale is named after William Thomson, 1st Baron Kelvin, also known as Lord Kelvin, who proposed the scale in 1848.



Room temperature is often considered to be $20\text{ }^{\circ}\text{C}$, or $68\text{ }^{\circ}\text{F}$, so 293 K is a temperature you will often find in problems. If you subtract 273 from a temperature in kelvins, you will be back at the Celsius temperature.

3 Molecules in Motion

Gases are quite different from liquids and solids. The molecules and atoms in solids and liquids are held close together by forces between molecules and atoms. Liquids lie in the bottom of any container they are in, and solids generally maintain their own shape without a container. In contrast, the molecules in gases expand to fill whatever space they are in. This indicates that there are essentially no forces between the molecules in a gas.

So, why is it that gas molecules are found throughout their container and not just at the bottom of it? And why is it that the space a gas occupies expands so dramatically as temperature increases? To explain many of the properties of gases, scientists rely on a model called the **kinetic theory of gases**. This model proposes that gas particles—atoms or molecules—are in constant motion. The word kinetic comes from a Greek word, *kinetos*, meaning “moving.”

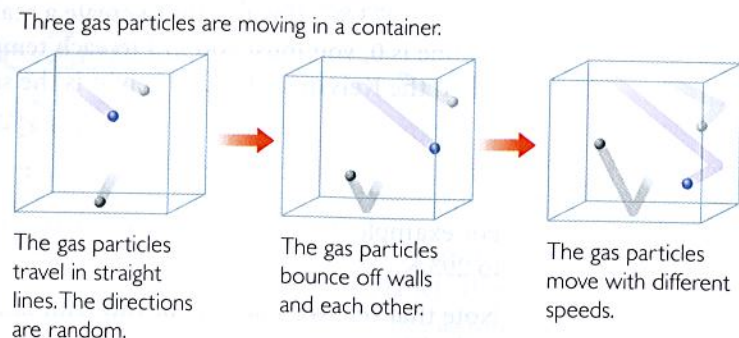
BIG IDEA On a particle level, all matter is in constant motion.

ASTRONOMY CONNECTION

The Boomerang Nebula is the coldest place known in the universe. It is 5000 light-years from Earth in the constellation Centaurus and has a temperature of 1 K.



These illustrations show the motion of three gas particles at three different times based on the kinetic theory of gases.



One characteristic of gases described by the kinetic theory is that not all the gas particles are moving with the same speed. For example, the gas particle shown in blue moves more from frame to frame than the one shown in gray. However, the kinetic theory focuses on the average speed for all the particles at a given temperature. Indeed, the **temperature** of a gas can be defined as a measure of the *average* kinetic energy of the gas particles. When the temperature increases, the average speed of the gas particles increases. Scientists hypothesize that if you could cool matter to absolute zero, the atoms in the substance would stop moving.

BIG IDEA Temperature is a measure of the average speed of the atoms or molecules in a sample.

Key Terms

absolute zero
Kelvin scale
kinetic theory of gases
temperature

Lesson Summary

How cold can substances become?

The Kelvin scale assigns a value of 0 K to the hypothetical temperature of a gas with zero volume. This point is called absolute zero and is at $-273\text{ }^{\circ}\text{C}$. Scientists consider this to be the lowest hypothetical temperature that matter can reach. They hypothesize that all motion stops at absolute zero. The kinetic theory of gases describes the motions of the gas particles. The atoms or molecules in a gas are constantly moving with an average speed that increases with increasing temperature.

EXERCISES

Reading Questions

1. What is absolute zero? Why is it considered a hypothetical temperature?
2. What advantages does the Kelvin scale have over the Celsius scale?

Reason and Apply

Use these for question #7

6. a. 100 K b. $60\text{ }^{\circ}\text{C}$ c. 250 K d. $25\text{ }^{\circ}\text{C}$ e. 300 K
f. $-100\text{ }^{\circ}\text{C}$ g. 400 K
7. Convert each of the Kelvin temperatures in Exercise 6 to degrees Celsius, and vice versa.
10. The temperature on the surface of Venus is 736 K. Convert this temperature into degrees Celsius. Describe what the atmosphere of Venus might be like.

HISTORY CONNECTION

The French inventor and physicist Guillaume Amontons first proposed the existence of absolute zero in 1702. Although he became deaf in his early teens, he did not allow this to stop him from having a productive scientific career. In addition to his work on temperature and pressure, Amontons developed the gas thermometer.

