Lesson 11 - Gases

Section 1 - Properties of Gases and the Kinetic Model

Open a bottle of perfume or cologne and you will soon smell it. This is because some particles in the bottle move into the air. This simple example shows how easily gas particles move around. Not all particles move this freely. From earlier lessons, you know that the particles of a solid are closely packed and cannot move far. As a result, a solid has a definite shape. The particles in a liquid can easily slide past each other. Thus, a liquid takes on the shape of its container. The volume of solids and liquids do not change much, even with changes in temperature. Gas particles have much more freedom of movement. They are relatively far apart. Unlike solids and liquids, the volume of a gas depends greatly on both temperature and pressure.

To understand gases, you need to know how energy, temperature, pressure, and volume are related. All of these are physical properties of matter.

Kinetic Energy, Particle Speed, and Temperature

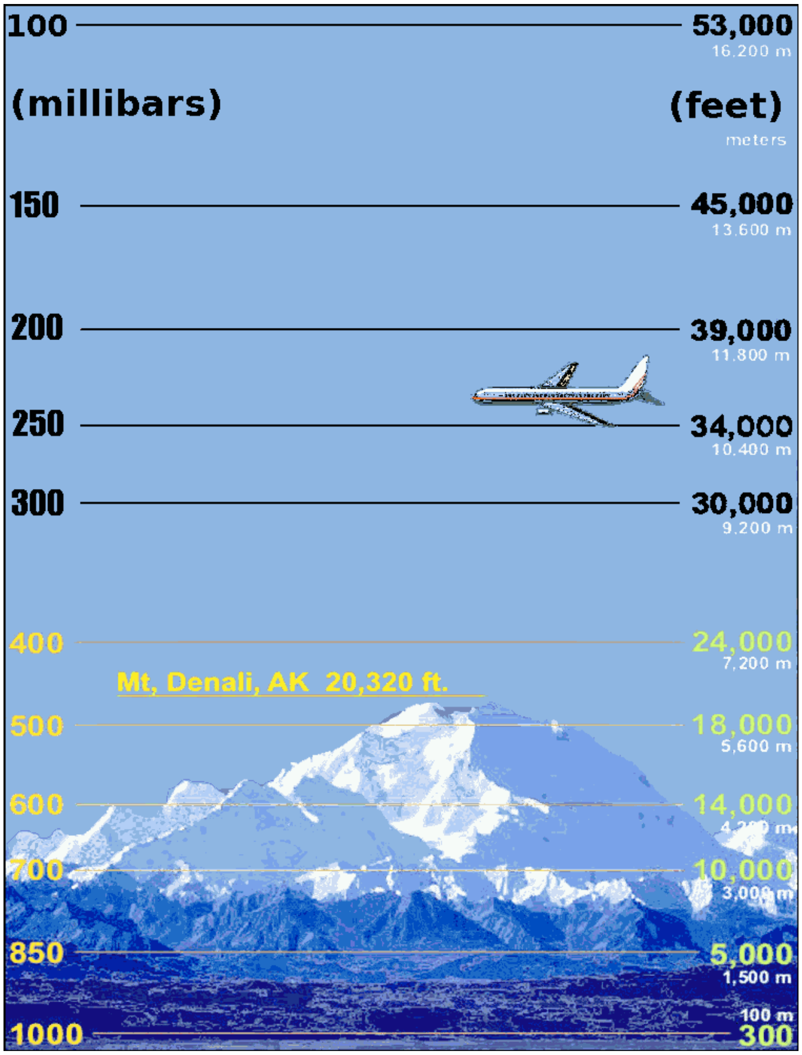
From earlier lessons, you know that kinetic energy is the energy of motion. Anything that is moving has kinetic energy. The particles in matter have kinetic energy. The temperature of a sample of matter is related to the kinetic energy of its particles. Temperature is a measure of average kinetic energy (particle speed). This is true for solids, liquids, and gases. As the temperature of a sample increases, so does the kinetic energy of its particles. This is because the average speed of the particles increases.

Pressure and Volume

Pressure is the force acting on a certain area. Compare two people walking on a wood floor. Both are the same weight. One is wearing tennis shoes, and the other is wearing high heels. Each person's weight is a force acting on the floor. The area of this force is the bottom of their shoes. The amount of force is the same for both, but the surface area of the high heels is much smaller. As a result, the person with high heels applies a greater pressure on the floor than the person with tennis shoes.

Pressure is a physical property of a gas. It is the force of billions of gas particles colliding with the walls of their container. The more collisions there are, the higher the gas pressure.

You live at the bottom of a "sea" of air called the atmosphere. Because of gravity, the weight of the atmosphere exerts a force on you and everything else on the earth's surface. **Atmospheric pressure** is the pressure exerted by the weight of the atmosphere. It is also called air pressure. Atmospheric pressure is exerted by the collisions of air molecules with other objects. There is less atmospheric pressure on top of a mountain than at sea level. When you are high in the atmosphere, there is less atmospheric weight pressing on you.



Gases expand to fill their container completely. The volume of a gas is the volume of its container. If the gas is in a sealed container, it expands to fill it. When a perfume bottle is opened, the gas in it quickly expands to fill the room. Because there is so much empty space between gas particles, a gas can be easily compressed, or packed into a smaller volume. Solids and liquids cannot be compressed very much. When a gas is compressed, the gas particles move closer together and collide more often with the walls of the container. As a result, the pressure of the gas increases.

The Kinetic Model

To understand how gas particles act, chemists use the concept of an **ideal gas**. Most gases are considered "ideal" at normal temperatures and pressures. The particles in an ideal gas are described by the **kinetic model**. This model is a set of assumptions about how particles act. It states that the particles in matter are in constant motion. The kinetic model is used to explain-the physical properties of gases. The kinetic model, also called kinetic-molecular theory, assumes the following:

- Gases are made of atoms (like He) or molecules (like CO_2). These particles are in constant motion. They act like tiny balls that are far apart from each other, bouncing around inside a container. Between the particles is empty space - nothing. The volume of the particles themselves is very small compared to the volume of empty space. Because of this, ideal gas particles are considered to have a volume of zero.
- Gas particles move randomly and travel in straight lines. Once in a while they collide with, or

hit, each other or some object. After a collision, a gas particle bounces off in another straight line. This is similar to billiard balls moving around on a pool table. Gas particles do not combine when they collide.

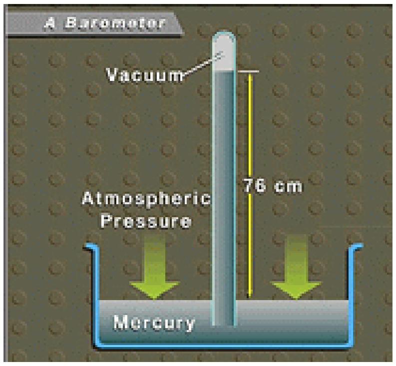
- Collisions between two gas particles or between a gas particle and another object conserve energy. In such a collision, the total kinetic energy of the colliding particles stays the same. No energy is lost. The energy is completely transferred. If energy was not conserved, gas particles would lose energy with each collision. The particles would slow down and eventually fall to the bottom of the container.

Section 2 - Measuring Pressure and Temperature

Suppose you want to calculate the volume of 100 g of a substance. If the substance is a solid or liquid, you would use its density to find the volume. If the substance is a solution, you would use its molarity. If the substance is a gas, you need to know its temperature and pressure. In this lesson, you will learn how these two properties are measured.

Pressure

Gas pressure can be measured in different ways and with different units. One tool that measures atmospheric pressure is a barometer. There are many types of barometers. The one in the figure below consists of a glass tube that is filled with liquid mercury and placed upside-down in a dish of mercury. The atmospheric pressure presses on the mercury in the dish. This pressure supports the mercury in the tube. When atmospheric pressure increases, the height of mercury in the tube rises.



This height—in millimeters of mercury (mm Hg)—is one unit of pressure. Gas pressure is also measured in units of atmospheres (atm) and pascals (Pa). The pascal is the official SI unit for pressure, although the kilopascal (kPa) is commonly used. Standard atmospheric pressure, 1.00 atm, is the same as 760. mm Hg or 101.3 kPa.

To convert from one pressure unit to another, use these equations in the form of conversion factors:

1.00 atm = 760. mm Hg = 101.3 kPa

Follow the basic conversion steps, remembering to put the desired unit on the top of the conversion factor.

Example 1

What is the pressure in atmospheres of a gas at 153 kPa?

The conversion factor you need is 1.00 atm = 101.3 kPa.

$$153 \text{ kPa} \left(\frac{1.00 \text{ atm}}{101.3 \text{ kPa}}\right) = 1.51 \text{ atm}$$

Example 2
What is the pressure in millimeters of mercury (mmHg) of a gas at 0.90 atm?

The conversion factor you use for this problem is 1.00 atm - 760 mmHg

$$0.90 \text{ atm} \left(\frac{760 \text{ mmHg}}{1.00 \text{ atm}}\right) = 684 \text{ mmHg}$$

Example 3
What is the pressure in kilopascals of a gas at 811 mmHg?

The conversion factor to use here is 760 mmHg = 101.3 kPa

$$811 \text{ mmHg} \left(\frac{101.3 \text{ kPa}}{760 \text{ mmHg}}\right) = 108 \text{ kPa}$$

Temperature

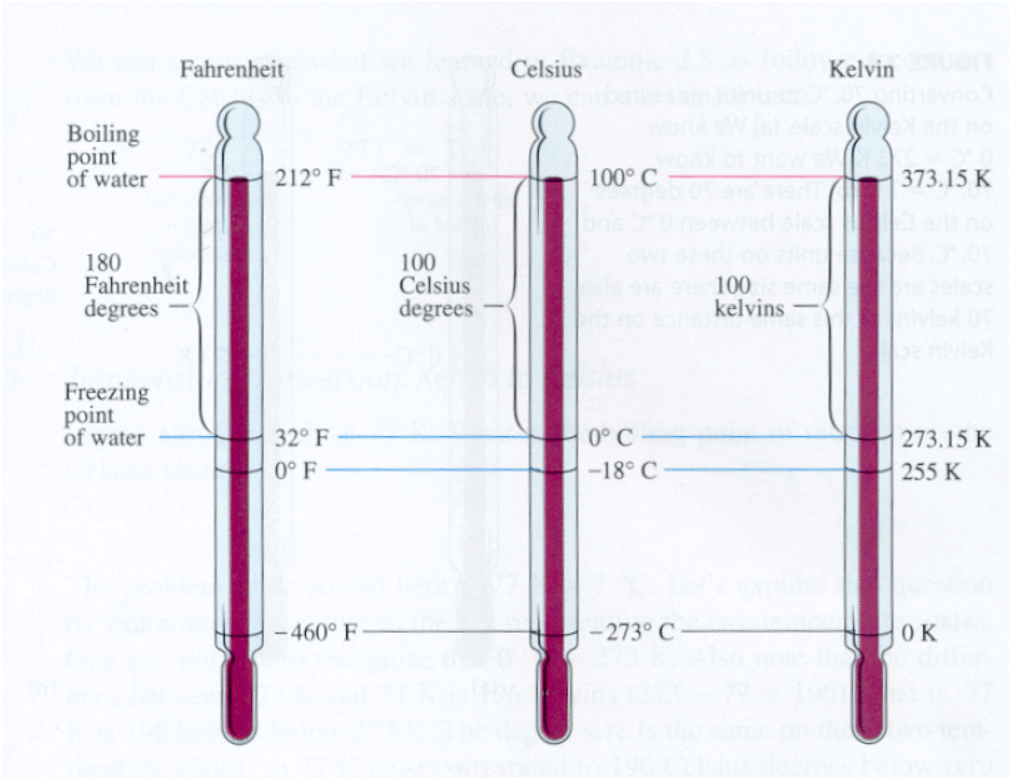
There are three different scales for measuring temperature. You are probably familiar with the Fahrenheit and Celsius scales. Both measure temperature in degrees (°F or °C). When working with gases, it is important to use absolute temperature, which is measured on the Kelvin scale.

Absolute temperature has no negative values. Its unit is the kelvin (K), the SI unit of temperature. The symbol K does not use a degree symbol. The lowest possible temperature is 0 K, called absolute zero. At absolute zero, the particles in matter stop moving. They have zero kinetic energy. Absolute zero, 0 K, is the same as — 273°C. This is an extremely cold temperature that has never been achieved in a laboratory. To convert from degrees Celsius to Kelvins, use this equation:

$T_k = T_c + 273$

T_c is a temperature in degrees Celsius, and T_k is a temperature in Kelvins. Remember from earlier lessons that standard temperature and pressure, STP, is 0°C and 1.00 atm. Under these conditions, 1 mol of a gas is 22.4 L. The temperature 0°C is the same as 273 K.

This is the temperature at which water freezes. The figure below compares the three temperature scales.


Fahrenheit
Celsius
Kelvin
Boiling point of water
212° F
100° C
373.15 K
180 Fahrenheit degrees
100 Celsius degrees
100 kelvins
Freezing point of water
32° F
0° C
273.15 K
0° F
−18° C
255 K
−460° F
−273° C
0 K