① words IDK ③ underline ideas IDK
② representative sketch

The Nature and Properties of Gases

There are five physical properties of gases.

Fluidity

Gases are fluid; that is, they can be poured form one container to another. The particles glide easily past one another; they are said to flow. The minimal attractive forces between gas particles permit this to happen easily.

Expansion

A gas will fill the entire volume of any container into which it is placed. If a gas appearing to have a volume of 3 Liters inside a container is placed in a container with a volume of 6 Liters, the gas will expand its volume to the 6 Liters of space available.

Compressibility

Particles of a gas are very far apart, with nothing between them except empty space. If pressure is applied to the gas sample, in order to relieve the pressure, the particles will move closer to one another and the sample will contain less empty space, thus occupying less volume. It is then said to be compressed. A SCUBA cylinder is an example of a compressed gas. The volume of air at atmospheric temperature and pressure is compressed into a SCUBA cylinder eight inches in diameter and 27 inches tall.

Low Density

Because the particles of a gas are so small and so far apart, a sample of a gas is mostly empty space and has very little mass for a large volume. This low mass/volume ratio is the reason for the low density of most gases. Instead of expressing gas density in grams/mL, most scientists use units of grams/Liter.

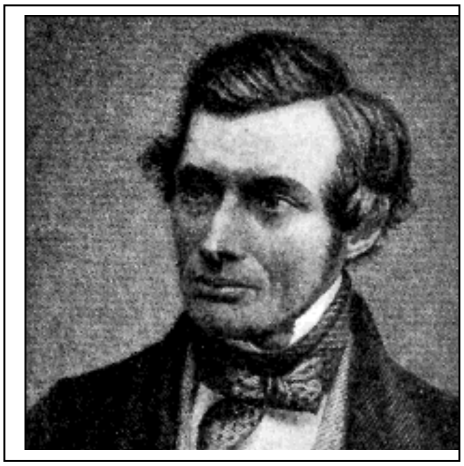
Diffusion

Diffusion is the spontaneous mixing of two gases that are in contact with one another. Different gases will mix throughout one another without any stirring, motion, or energy input from an outside source. Odors are a perfect example of diffusion. Once gases diffuse through one another and are thoroughly mixed, they do not separate spontaneously. It takes a good deal of effort to separate them again.

Effusion is a similar process, but the gases contact each other through only a small opening in their containers. They mix only through a small opening between them.

The rates by which gases mix through diffusion or effusion is directly proportional to their molecular masses, as is illustrated by Graham's Law. A larger molecule will move more slowly that a smaller one.

Graham's Law



This concept was discovered by Thomas Graham of Scotland in the 1830s. Consider samples of two different gases at the same Kelvin temperature. Since temperature is proportional to the kinetic energy of the gas molecules, the kinetic energy (KE) of the two gas samples is also the same.

In equation form, we can write: $KE_1 = KE_2$

Since $KE = (1/2)\,mv^2$, (m = mass and v = velocity) and allowing the 1/2 to cancel, the new equation is written:

$$m_1 v_1^2 = m_2 v_2^2$$

Which rearranges to $\dfrac{m_2}{m_1} = \dfrac{v_1^2}{v_2^2}$

Rearranging, then taking the square root of both sides, the equation becomes

$$\frac{\sqrt{m2}}{\sqrt{m1}} = \frac{v1}{v2}$$

This last equation is the useful version of Graham's law. It shows mathematically that the particle with the higher molar mass will move proportionately more slowly than the particle with lower molar mass. The exact proportions are shown by the equation above. Note the velocities of the gases are inverse to the molar masses and that the exact velocities need not be known to find a ratio comparing the velocities.

A sample problem follows:

What is the relative rate of diffusion of Krypton and Bromine?

Solution:
First, find the molecular masses (in this case, formula weights since krypton is an atom) for the two gases. By convention, the heavier particle is assigned the variable m_2. This makes the rate value found easier to interpret.

Formula Weight of krypton: $83.8\ \mu = m_1$
Formula Weight of Bromine: $159.9\ \mu = m_2$

Next, use the Graham's Law Formula:

$$\frac{\sqrt{m_2}}{\sqrt{m_1}} = \frac{v_1}{v_2}$$

Substitute in the correct values :

$$\frac{\sqrt{159.8}}{\sqrt{83.8}} = \frac{v_1}{v_2}$$

Take the square root of each value, then divide the top number by the bottom number to find the value 1.38. Interpreting this value with respect to the right side of the equation, it can be seen that v_1, which is krypton, diffuses 1.38 times as fast as v_2, bromine, which has a heavier formula weight. A quick check for reasonableness shows that the heavier particle was found to move more slowly.

The formal statement of Graham's Law:
The relative rates of diffusion for two gases under identical conditions of temperature and pressure are inversely proportional to the square roots of the molecular masses of the gases. This kind of law is known as an inverse square law.

The Kinetic Theory

The Kinetic Theory describes the motion of particles within a gas, liquid, or solid. As with all theories, this is an attempt to explain the observed behavior of each phase; solid, liquid, or gas.

The term **kinetic** comes from the Greek word *kinetikos* and means "moving." The kinetic theory, therefore, is based on the idea that the particles of matter are always moving, and that this motion has consequences. This idea applies to solids, liquids, and gases. The behavior of gases will be examined in this section.

The five assumptions of the Kinetic Theory follow:

1. All matter is composed of many tiny, discrete particles, usually molecules or atoms.

2. These particles move constantly and rapidly in random, straight lines, showing that they possess kinetic energy.

3. Molecules collide with each another and the sides of the container in perfectly elastic collisions in which all energy is conserved.

   → no chemical reaction

4. There are no attractive or repulsive forces between gas molecules or between molecules and the sides of the container with which they collide.

5. The average kinetic energy of the particles of a gas is directly proportional to the Kelvin temperature. $T\,°C + 273.14 = T\,K$

Any gas adhering strictly to these rules is known as an ideal gas. In reality, there are no ideal gases. Some gases will, at times, behave more or less like an ideal gas, but none will fit this description perfectly. Examine the conditions under which a real gas behaves more like an ideal gas.

Here are some ways in which real gases deviate from ideal gas behavior:

1. The particles of real gases have size; notably volume. They take up space. The particles of a gas are very, very tiny in comparison to the space between them. In any gas, the particles themselves take up about 1/1000 the total volume of the gas sample. The rest of the sample is totally empty space between the particles, space through which they may move as a result of their energy. The space actually occupied by molecules of a gas is totally ignored when using the Ideal Gas Law to calculate other properties of a gas, and the molecules are taken to be point masses, or dimensionless points so small that they are considered to occupy zero volume.

2. Real gases have attractive and repulsive forces. They might consist of polar molecules such as water vapor, with a positive side to stick to the negative side of another molecule. They may be ions, in which case two particles with like charges will repel each other. In a real gas, there actually is attraction between the molecules of a gas. Once again, this attraction WILL BE IGNORED when discussing ideal gases.

3. Total energy of the sample is conserved in elastic collisions, although it may be transferred between individual particles. One molecule may gain energy at the expense of another. At any particular instant, the molecules in a given sample of gas do not all have the same amount of energy. The average kinetic energy of all the molecules is proportional to the absolute temperature.

The molecules of real gases DO occupy volume. This has a definite impact upon the behavior of the gas. This impact WILL BE IGNORED and considered negligible when discussing ideal gases. The motion of particles can be described by Newton's Laws of Motion.

Gases will behave more or less like an ideal gas depending upon the conditions, especially those of pressure and temperature. Look at the effects pressure and temperature changes have on a gas to help explain the conditions under which the gas will behave most like an ideal gas. The above assumptions, sometimes called postulates, will help with this understanding.

A Note About Theories:

A theory is a generalization that explains a phenomena or related group of known facts. It is nothing more nor anything less than this.

Successful theories may predict the outcome of future experiments or trials.

A theory is not a guess, nor is its purpose to be proven and turned into a law.

A theory may support many observations about the phenomenon. The assumptions of the Kinetic Molecular Theory help explain five physical properties of a gas, listed below.