Intermolecular Forces and Properties
3.5 Kinetic Molecular Theory
Worksheet Key

1) A ridged 1.0 L cylinder contains 1.0 moles of O_2 gas at 25.0°C and another ridged 1.0 L cylinder contains 1.0 moles of CH_4 gas at 25.0°C. Is the average speed of the O_2 gas particles greater than, less than, or the same as the average speed of the CH_4 gas particles? Justify your answer.

Temperature is a measure of the average kinetic energy of the particles in a system. Since both systems are at the same temperature, the gas particles in both systems will possess the same average kinetic energy. The basic formula for kinetic energy is: $KE = ½ mv^2$. This tells us that the molecules with the smallest molar mass will have the largest average velocity. The atomic mass of O_2 is 32 g/mol and the atomic mass of CH_4 is 16 g/mol. Since CH_4 has the smaller molar mass, the particles in that system will have the largest average velocity.

2) According to kinetic molecular theory, does a gas molecule move slower after it bounces off of the wall of a container? Explain.

No, it will continue to move at the same speed. Kinetic molecular theory states that all collisions between gas particles and the walls of a container are elastic. No kinetic energy is lost in elastic collisions. If no kinetic energy is lost, then the velocity of the gas molecule must remain the same, as $KE = \frac{1}{2}mv^2$. The molecule does not lose any mass during the collision, so it cannot lose any velocity if it retains the same amount of kinetic energy.

3) What assumption does the ideal gas law make about the volume of gas particles in a system? Explain.

Ideal gas law assumes that the volume occupied by the gas particles in a system is negligible. The volume variable in the ideal gas law equation is the volume of empty space in the container and it assumes that the volume occupied by the gas particles is zero.

4) According to kinetic molecular theory, when two gas particles that share the same molar mass collide, is the sum of their velocities after the collision less than, equal to, or greater than the sum of their velocities before the collision? Justify your answer.

The sum of their velocities would be the same before and after the collision. According to kinetic molecular theory, all collisions between gas particles are elastic, which means that no kinetic energy is lost. Since the masses of the two gas particles do not change after they collide, the sum of their velocities does not change either.

$$KE_{\text{initial(I)}} + KE_{\text{initial(II)}} = KE_{\text{final(I)}} + KE_{\text{final(II)}}$$

$$\frac{1}{2}mv^2_{\text{initial(I)}} + \frac{1}{2}mv^2_{\text{initial(II)}} = \frac{1}{2}mv^2_{\text{final(I)}} + \frac{1}{2}mv^2_{\text{final(II)}}$$

$$\frac{1}{2}m(v^2_{\text{initial(I)}} + v^2_{\text{initial(II)}}) = \frac{1}{2}m(v^2_{\text{final(I)}} + v^2_{\text{final(II)}})$$

$$(v^2_{\text{initial(I)}} + v^2_{\text{initial(II)}}) = (v^2_{\text{final(I)}} + v^2_{\text{final(II)}})$$

5) According to kinetic molecular theory, when two gas particles that have different molar masses collide, is the sum of their velocities after the collision always going to be the same? Justify your answer.

It is very unlikely that the sum of their velocities would be the same. This would only happen if each particle continued to move at the exact same speed after they collided. The sum of their kinetic energies would be same before and after the collision, but because they have different molar masses the sum of their velocities would most likely be different.

$$KE = \frac{1}{2}mv^2$$

6) A gaseous system is kept at 25.0°C. A chemist slowly increase the temperature of the system until it reaches 50.0°C. Did the average kinetic energy of the gas particles in the system double when he did this. Justify your answer.

The average kinetic energy of the gaseous particles in the system increases, but it did not double. The average kinetic energy of the particles in a system is proportional to the Kelvin temperature scale (absolute temperature). If the temperate in Kelvin doubled, the average kinetic energy would have double. However, this did not occur.

$$25.0 + 273 = 298\text{K}$$

$$50.0 + 273 = 323\text{K}$$

2 x 298 K does not equal 323 K

7) Suppose you have two identical 1.0 L sealed containers. Both containers are kept at exactly 25°C. One vessel contains only neon gas at 1.5 atm, and the other contains only xenon gas at 2.5 atm.
   a. Is the average kinetic energy possessed by the neon atoms greater than, equal to, or less than that of the xenon atoms? Explain.

The average kinetic energy possessed by the neon atoms is equal to that of the xenon atoms. Temperature is a measure of the average kinetic energy of the particles in a system. Equal temperatures means that the average kinetic energies are also equal.

b. What variable must be changed in order to decrease the average kinetic energy of the xenon atoms?

Decreasing the temperature is the only method for decreasing the average kinetic energy of any system.

c. Does the vessel with the xenon gas contains more, fewer, or the same number of gas particles as the vessel of neon gas? Explain.

Both vessels are 1.0L and 25°C. The pressure in the vessel with the Xe gas is higher, so there must be more moles of gas in that container. When there are more moles of gas occupying the same volume, when both systems are at the same temperature, there will be more collisions per unit of time with the walls of the container; and therefore, the pressure will be higher.

8) Suppose you have two identical 2.0 L cylinders. Both cylinders are kept at exactly 25°C. One cylinder contains 0.250 moles of helium, and the other contains 0.250 moles of krypton. The volumes of these cylinders can change.
   a. Explain why these two gases do not share the same velocity under these conditions.

The root mean square velocity of helium is greater than that of krypton. This is due to the fact that the molar mass of helium is less than that of krypton. The square root of the molar mass is in the denominator of the equation. A smaller denominator (molar mass), will yield a higher velocity. The temperature is the same for both gases. The molar mass is the only variable that changes.

b. What variable must change in order to increase the average velocity of the molecules in either cylinder? Explain.

The temperature must increase in order to increase the average speed of the atoms in either container.