Workshop Tutorials for Introductory Physics

TI5: **Kinetic Theory**

A. Review of Basic Ideas:

Use the following words to fill in the blanks:
kinetic energy, pressure, number, momentum, molecules, mole, macroscopic, kinetic, force, $PV = nRT$, increase

Kinetic Theory

Properties of materials can be described at the _________ level, which we can see and measure easily or at the microscopic level where special equipment is needed to observe what is happening to atoms and _________. For example, the pressure of a gas can be described as the ________ per unit area exerted by the gas on a surface or can be thought of as the _________ imparted to the surface by the molecules of the gas. Similarly we can talk of the temperature of a gas and measure it with a thermometer or we can say the temperature of a gas is determined by the average _________ energy of the gas molecules.

Kinetic theory describes the properties of gases at the molecular level. In particular it describes the temperature, T, pressure, P, and volume, V, of a gas and how they are related. For an ideal gas - one where there is no attraction between the molecules - it can be shown that ___________ where n represents the number of moles of gas and R is the universal gas constant. One _________ contains 6.023×10^{24} molecules of gas. It is interesting to note that this equation does not depend on the type of molecule, but rather on the _________ of molecules present.

Real gases can be considered as ideal when the density of the gas is low enough so that attraction between the molecules is negligible. The equation above shows us that if we keep the volume constant and _________ the temperature then the pressure will increase. We can think about this at the molecular level. Increasing the temperature increases the average kinetic of the molecules, so when they collide with the surfaces of the container we would expect to see a greater change in momentum as they reverse direction. Hence the _________ is greater.

Kinetic theory can also explain why evaporation from your skin (perspiration) helps you stay cool. Those molecules with the greatest ________ ________ are more likely to escape from your body thus reducing the average kinetic energy of those left behind, thus reducing your temperature.

B. Activity Questions:

1. 2D model of gases

What happens when you increase the “temperature” of the gas?
How do the pressure and volume change?

2. Water boiling at less than 100°C

Can you make the warm water in the syringe boil?
Why does it boil at this lower temperature?

3. Blowing

Blow on your hands as if it was a cold day and you were trying to warm them.
Now blow on them as if you were blowing a hot drink to cool it.
How can you both heat and cool by blowing?
What do you do differently in each case, and why does it work?

4. Dropper
Use the dropper to pick up some liquid.
What holds the liquid in the dropper?
Explain why it doesn't fall out.

5. Boyle's law.
Take four or five measurements of pressure and volume using the apparatus provide.
Plot these points. Do they agree with the gas laws?

C. Qualitative Questions.

1. Two equal-sized rooms communicate through an open doorway. However, the average temperatures in the two rooms are maintained at different values.
a. In which room are there more air molecules? Explain your answer.
b. In which room will the average speed of the molecules be lower? Why?

2. Brent has bought Rebecca a new pressure cooker for her birthday. Rebecca is a bit skeptical about the device, but decided to cook a casserole in it to test it out. The pressure cooker is a fancy one, and comes with a cookbook. One recipe lists the cooking time for a chicken casserole as only 20 minutes. "Wow!" says Rebecca "that usually takes at least 45 minutes to cook!"
a. Why does food cook so much faster in a pressure cooker than in a saucepan?
After cooking the casserole, Rebecca insists they let it cool a few minutes. She explains that its much hotter than if she'd cooked it in a saucepan, so they'd better let it cool a little before tucking in.
b. Is the casserole much hotter than one from a saucepan? What limits the temperature of a normal saucepan and a pressure cooker?

D. Quantitative questions.

Valuable documents and artifacts are sometimes kept in an inert atmosphere to stop them from decomposing, for example the declaration of independence in the US is kept in a sealed vault under nitrogen. A local museum is setting up a display of early Australian flags, including the original flag from the Eureka Stockade in Ballarat. They have a glass case specially made in which to display the flag. The case has a volume of 8 litres. The flag is laid out and nitrogen (N_2 gas) is pumped into the case to displace the air, so that it contains only nitrogen gas at atmospheric pressure. This is done at night when the temperature is 8^{o}C, so that the display can be launched at a ceremony the next morning. The next day is very hot, and it gets up to 35^{o}C. During the ceremony someone notices a hissing sound coming from the case, and a leak is discovered. The leak is fixed, but not before enough nitrogen has escaped so that the pressure has reached equilibrium. That evening, when the temperature has dropped back to 8^{o}C again, the pressure inside the case is measured.
a. How much nitrogen (in grams) remains in the case?
b. How much nitrogen has been lost from the case? How much will need to be added to refill the case to atmospheric pressure?
c. What is the pressure inside the case now, before it is refilled?

Data:
Gas constant R = 8.31 J.mol^{-1}.K^{-1}
Molar mass of nitrogen gas = 28 g.mole^{-1}.