CH301 2008 Worksheet 9 on Gases

1. What are the assumptions of Kinetic Molecular Theory?

Answer: Gases have no volume (infinitely small), gas molecules do not interact with one another (no attractions or repulsions). As a result, they collide elastically (no energy is lost).

2. For the following variable pairs, tell if they have directly proportional or inversely proportional relationships:

a. V & T
b. P & T
c. n & P
d. P & V

Answer: a. proportional , b. proportional, c. proportional, d. inverse. These can be figured out by looking at the ideal gas law, PV = nRT.

3. The ideal gas law can be used to solve for the molecular weight of an unknown gas. If 1 g of a hypothetical molecule at STP takes up 1 L of volume, what is the molecular weight of that molecule?

Answer: We can use the ideal gas law here, substituting using n = m/M where m is mass and M is molecular weight. Solving for M, we find M = mRT/PV. Plugging in, M = (1 g * 0.0821 L atm per mole per K * 273 K / (1 atm * 1 L) = 22.4 g/mol

4. You should know that many gases do not behave ideally and therefore do not obey the ideal gas law. How do we correct for this in real life calculations when we need more accurate answers?

Answer: Real gases can still be approximated by the ideal gas law. To improve the accuracy of our calculations, we can add corrections or "fudge factors". Probably the most common example of this is the Vanderwaal's equation, which has a form similar to the ideal gas law but with adjustments to the P and V terms.

5. Describe the relationship between diffusion, effusion, and gas speed.

Answer: They are all proportional. Higher gas speeds lead to higher diffusion rates and higher effusion rates.

6. If two gas molecules have the same kinetic energy, which will move faster, the larger molecule or the smaller molecule? WHY?

Answer: The smaller molecule will move faster. The kinetic energy is described by $E = (1/2)mv^2$. Since E is the same for both molecules, the larger molecule must have a smaller velocity.

7. As temperature increases, what happens to the average kinetic energy of the molecules in a gas? What would you expect to happen to the rate of diffusion and effusion?

Answer: Higher temperature increases the average kinetic energy of the molecules. In other words, the molecules are flying around faster if it's hot! This will result in a corresponding increase in the rates of effusion and diffusion.

8. Balloons will change size depending on room temperature. Explain why.

Answer: Charle's law tells us that if the temperature is higher, the volume must also increase. Similarly, if the temperature is lower, the volume must decrease. Go put a balloon in your fridge, you will learn so much science!

9. Explain, in terms of collisions, why you expect a balloon with more gas in it to be larger than a less filled balloon?

Answer: If there are more molecules of gas, the walls of the balloon will experience more frequent collisions with the gas. The gas exerts a pressure on the walls of the balloon forcing it to stretch open wider.

10. Which do you think behaves more ideally, water vapor or difluorine gas? On what do you base your considerations?

Answer: If you compare the polarity, difluorine gas should be more ideal because it is nonpolar. Water vapor, on the other hand, is highly polar and also can hydrogen bond. It definitely violates our assumptions about molecules not interacting with one another. If you compare the molecular size (by the molecular weight), you would predict that difluorine is less ideal because it is slightly larger. Don't worry, when we ask you about the ideality of gases we won't make it ambiguous like this. Just trying to get you thinking!

11. If we completely combust 6 moles of glucose ($C_6H_{12}O_6$) in the presence of excess oxygen. The reaction occurs in a 22 liter container at standard temperature, what would be the total final pressure of the system in atmospheres?

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2\,(g) + 6H_2O\,(l)$$

Answer: 40 atm. Hydrolyzing 6 moles of glucose would yield 36 moles of carbon dioxide (n=36 moles). $P = (nRT)/V = (36\text{ mol} \times 0.0821\text{ L·atm·mol}^{-1}\text{·K}^{-1} \times 298\text{ K})/22\text{ L} = 40\text{ atm}$.

12. A sample of sulfur vapor at 100°C exerts a pressure of 0.75 atm on the walls of its container. If a researcher raises the temperature in the container to 200 °C while holding all other factors constant, what will be the resulting pressure in the container due to the sulfur vapor?

Answer: 0.95 atm. Convert the temperatures to Kelvin. Since PV=nRT, pressure is directly proportional to temperature. Thus the ratio of the temperatures would give the ratio of pressures: P1/P2 = T1/T2. Plugging in the numbers (P1/0.75 atm = 473K/373K) and solving for pressures give 0.95 atm.

13. In an industrial process, nitrogen is heated to 500K in a vessel of constant volume. If it enters the vessel at 100 atm and 300 K, what pressure would it exert at the working temperature if it behaved like an ideal gas?

Answer: 167 atm. Since the volume and amount of the gas are both fixed, the only variables are pressure and temperature, which are again inversely related. Again, taking the ratio of pressures and temperatures would give P1/P2 = T1/T2. Plugging in the numbers and solving for pressure (P1/100 atm = 500 K/ 300K) gives 167 atm.

14. If 56g of liquid nitrogen (N_2) to evaporate at standard temperature and pressure, what is the final volume of the gaseous nitrogen?

Answer: 49 atm. 56 g of nitrogen is 2 moles. $V = (nRT)/P = (2\text{ mol} \times 0.0821\text{ L·atm·mol}^{-1}\text{·K}^{-1} \times 298\text{ K})/1\text{ atm} = 49\text{ L}$.

15. If 56g of liquid nitrogen (N_2) to evaporate at standard temperature in a 2 L container, what is the final pressure of the gaseous nitrogen?

Answer: 24 atm. 56 g of nitrogen is 2 moles. P = (nRT)/V = (2 mol x 0.0821 L·atm·mol^{-1}·K^{-1} x 298 K)/2 L = 24 L.

16. Explain diffusion in terms of molecular movement.

Answer: Diffusion is caused by molecular movement and is the net directional motion of all the molecules combined.

17. What is the density of CO_2 gas maintained at a pressure of 1 atm and temperature of 300 K?

Answer: 1.8 g/l. PV= nRT. Density = mass/volume = n x MW / V = PV/(RT) x MW / V = P x MW / RT = 1 x 44 g/mol / (0.0821 L·atm·mol^{-1}·K^{-1} x 300 K) = 1.8 g/L

18. Considering the oxygen molecule (N_2) and the much smaller hydrogen molecule (H_2), which one has a greater kinetic energy?

Answer: At a given temperature, all gas molecules, regardless of their size, have the same energy.

19. Considering the nitrogen molecule (N_2) and the much smaller hydrogen molecule (H_2). If at a given temperature, N_2 travels at the rate of 100m/s, what is the speed of H_2? How would the two molecules compare in their rate of diffusion?

Answer: 374 m/s. E = ½ mv^2. Since energy is the same, the ratio v^2 (nitrogen) / v^2 (hydrogen) = mass (hydrogen)/ mass (nitrogen) = 1/14. Thus the speed of H_2 = 100 m/s x √(14) = 100 m/s x 3.74 = 374 m/s. Nitrogen would diffuse 3.74 fold slower than hydrogen.

20. What are some factors that cause non-ideality in gases? What conditions would minimize these factors?

Answer: Size of the molecule (Larger molecules, evaluated by atomic mass, are less ideal). Intermolecular attractions (Greater attractions=more inelastic collisions= less ideal). Low pressure would minimize intermolecular attractions by increasing the intermolecular distance. High temperature would also increase the energy of the molecules, making the energy lost in collisions less significant.