**Gas laws worksheet (2-08) (modified 3/17)**
**Answer key**

**Graham's Law**

1. Calculate the ratio of effusion rates for nitrogen ($N_2$) and neon (Ne).

$$\frac{\upsilon_A}{\upsilon_B} = \frac{\sqrt{M_B}}{\sqrt{M_A}} = \frac{\sqrt{20}}{\sqrt{28}} = \mathbf{0.845}$$

2. Calculate the ratio of diffusion rates for carbon monoxide (CO) and carbon dioxide ($CO_2$).

$$\frac{\upsilon_A}{\upsilon_B} = \frac{\sqrt{M_B}}{\sqrt{M_A}} = \frac{\sqrt{44}}{\sqrt{28}} = \mathbf{1.25}$$

3. What is the rate of effusion for a gas that has a molar mass twice that of a gas that effuses at a rate of 3.6 mol/min?

$$\frac{\upsilon_A}{\upsilon_B} = \frac{\sqrt{M_B}}{\sqrt{M_A}} \quad \frac{3.6}{y} = \frac{\sqrt{2x}}{\sqrt{x}} \quad \frac{3.6}{y} = 1.4 \qquad 3.6 = 1.4\,y \text{ so } \mathbf{y = 2.5\ mol/min}$$

**Dalton's Law**

4. Find the total pressure for a mixture that contains four gases with partial pressures of 5.00 kPa, 4.56 kPa, 3.02 kPa, and 1.20 kPa. **13.78 kPa**

5. Find the partial pressure of carbon dioxide in a gas mixture with a total pressure of 30.4 kPa if the partial pressures of the other two gases in the mixture are 16.5 kPa and 3.7 kPa. **10.2 kPa**

6. What assumption of the kinetic-molecular theory explains why a gas can expand to fill a container? The assumption that gas particles are in constant and random motion.

7. How does the mass of a gas particle affect its rate of effusion? Greater mass, slower rate of effusion; inversely proportional.

8. Explain how changes in atmospheric pressure affect the height of the column of mercury in a barometer. An increase in atmospheric pressure increases the pressure on the surface of mercury and the column rises; a decrease in atmospheric pressure decreases the pressure on the surface of the mercury and the column drops.

9. Explain why a tire or balloon expands when air is added. When air is added more particles are added and therefore there are more collisions between air particles and the walls, exerting greater pressure inside the balloon or tire and expanding the walls.

10. Explain why the container of water must be inverted when a gas is collected by displacement of water. If the container is not inverted, the gas, which is less dense than water, will rise through the water and escape from the opening of the container.

***Boyle's Law***

11. The volume of a gas at 99.0 kPa is 300.0 ml. If the pressure is increased to 188 kPa, what will be the new volume?

$$P_1V_1 = P_2V_2 \qquad V_2 = \frac{P_1V_1}{P_2} = \frac{(99.0\text{ kPa})(300.0\text{ ml})}{188\text{ kPa}} = \mathbf{158\ ml}$$

12. The pressure of a sample of helium in a 1.00-liter container is 0.988 atm. What is the new pressure if the sample is placed in a 2.00-liter container?

$$P_1V_1 = P_2V_2 \qquad P_2 = \frac{P_1V_1}{V_2} = \frac{(0.988\text{ atm})(1.00\text{ liter})}{2.00\text{ liter}} = \mathbf{0.494.atm}$$

***Charles's Law***

13. A gas at 89°C occupies a volume of 0.67 liter. At what Celsius temperature will the volume increase to 1.12 liters?

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad T_2 = \frac{T_1V_2}{V_1} = \frac{(89+273)(1.12\text{ liters})}{0.67\text{ liter}} = 605\text{ K} - 273 = \mathbf{332°C}$$

14. What is the volume of the air in a balloon that occupies 0.620 liter at 25°C if the temperature is lowered to 0.00°C?

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad V_2 = \frac{V_1T_2}{T_1} = \frac{(0.620\text{ liter})(273\text{ K})}{298\text{ K}} = \mathbf{0.568\text{ liter}}$$

***Gay-Lussac's Law***

15. A gas in a sealed container has a pressure of 125 kPa at a temperature of 30.0 °C. If the pressure in the container is increased to 201 kPa, what is the new temperature?

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \quad T_2 = \frac{T_1P_2}{P_1} = \frac{(201\text{ kPa})(303\text{ K})}{125\text{ kPa}} = 487\text{ K} - 273 = \mathbf{214°C}$$

16. The pressure in an automobile tire is 1.88 atm at 25.0 °C. What will be the pressure if the temperature warms up to 37.0 °C?

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \quad P_2 = \frac{P_1T_2}{T_1} = \frac{(1.88\text{ atm})(310\text{ K})}{298\text{ K}} = \mathbf{1.96\text{ atm}}$$

17. Explain why gases such as the oxygen found in tanks used at hospitals are compressed. Why must care be taken to prevent compressed gases from reaching a high temperature? A greater mass confined to a smaller volume makes transporting and storage easier. But, increasing the temperature would cause the pressure to increase and possibly make the canisters explode.

***Combined gas law and Avogadro's principle***

18. A helium filled balloon at sea level has a volume of 2.1 liters at 0.998 atm and 36 °C. If it is released and rises to an elevation at which the pressure is 0.900 atm and the temperature is 28 °C, what will be the new volume of the balloon?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{(0.998\text{ atm})(2.1\text{ liters})(301\text{ K})}{(309\text{ K})(0.900\text{ atm})} = \mathbf{2.27\text{ liters}}$$

19. At 0.00 °C and 1.00 atm pressure, a sample of gas occupies 30.0 ml. If the temperature is increased to 30.0 °C and the entire gas sample is transferred to a 20.0 ml container, what will be the gas pressure inside the container?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad P_2 = \frac{P_1V_1T_2}{T_1V_2} = \frac{(1.00\text{ atm})(30.0\text{ ml})(303\text{ K})}{(273\text{ K})(20.0\text{ ml})} = \mathbf{1.66\text{ atm}}$$

20. Determine the volume of a container that holds 2.4 mol of gas at STP.

$$2.4\text{ mol} \times \frac{22.4\text{ liter}}{1\text{ mole}} = \mathbf{53.76\text{ liters}}$$

21. How many moles of nitrogen gas will be contained in a 2.00-liter flask at STP?

$$2.00\text{ liter} \times \frac{1\text{ mole}}{22.4\text{ liters}} = \mathbf{0.089\text{ mole}}$$

22. If a balloon will rise off the ground when it contains 0.0226 mol of helium in a volume of 0.460 liter, how many moles of helium are needed to make the balloon rise when its volume is 0.865 l? Assume that temperature and pressure stay constant.

$$\frac{0.0226 \text{ mol}}{0.460 \text{ liter}} = \frac{X \text{ mole}}{0.865 \text{ liter}} \qquad X = \frac{(0.0226 \text{ mol})(0.865 \text{ liter})}{(0.460 \text{ liter})} = \mathbf{0.042 \text{ mol}}$$

23. How many grams of carbon dioxide gas are in a 1.00 l balloon at STP?

$$1.00 \text{ liter} \times \frac{1 \text{ mole}}{22.4 \text{ liter}} \times \frac{44 \text{ g } CO_2}{1 \text{ mole}} = \mathbf{1.96 \text{ grams}}$$

24. A flexible plastic container contains 0.860 g of helium gas in a volume of 19.2 liters. If 0.205 g of helium is removed without changing the pressure or temperature, what will be the new volume?

$$\frac{0.860 \text{ g}}{19.2 \text{ liter}} = \frac{0.655 \text{ g}}{X} \qquad X = \frac{(19.2 \text{ liter})(0.655 \text{ g})}{(0.860 \text{ g})} = \mathbf{14.6 \text{ liter}}$$

25. Think about what happens when a bottle of carbonated soft drink is shaken before being opened. Use the gas laws to explain whether the effect will be greater when the liquid is warm or cold. Shaking the soda increases the kinetic energy of the molecules, thus raising the temperature and pressure. Shaking it before opening allows the gas bubbles to escape quickly. This is more pronounced when it is warm as the KE of the molecules is greater at a warmer temperature.

26. Imagine that you are going on an airplane trip in an unpressurized plane. You are bringing aboard an air-filled pillow that you have inflated fully. Predict what will happen when you try to use the pillow while the plane is at its cruising altitude. If the air in the plane is not fully pressurized, the air inside the pillow will expand as the plane ascends because volume is inversely proportional to pressure.

***Ideal Gas Law***

27. If the pressure exerted by a gas at 25°C in a volume of 0.044 liter is 3.81 atm., how many moles of gas are present?

$$PV = nRT \qquad n = \frac{PV}{RT} = \frac{(3.81 \text{ atm})(0.044 \text{ liter})}{(0.0821 \text{ l·atm/mole·K})(298 \text{ K})} = \mathbf{0.00685 \text{ mole}}$$

28. Calculate the volume that a 0.323-mol sample of a gas will occupy at 265 K and a pressure of 0.900 atm.

$$PV = nRT \qquad V = \frac{nRT}{P} = \frac{(0.323 \text{ mol})(0.0821 \text{ l·atm/mole·K})(265 \text{ K})}{0.900 \text{ atm}} = \mathbf{7.81 \text{ liters}}$$

29. What is the pressure in atmospheres of a 0.108-mol sample of helium gas at a temperature of 20.0°C if its volume is 0.505 liter?

$$PV = nRT \qquad P = \frac{nRT}{V} = \frac{(0.108 \text{ mol})(0.821 \text{ l·atm/mole·K})(293 \text{ K})}{(0.505 \text{ liter})} = \mathbf{5.144 \text{ atm}}$$

30. Determine the Kelvin temperature required for 0.0470 mol of gas to fill a balloon to 1.20 liter under 0.988 atm pressure.

$$PV = nRT \qquad T = \frac{PV}{nR} = \frac{(0.988 \text{ atm})(1.20 \text{ liter})}{(0.047 \text{ mol})(0.0821 \text{ l·atm/mole·K})} = \mathbf{307 \text{ K}}$$

31. Calculate the grams of $N_2$ gas present in a 0.600-liter sample kept at 1.00 atm pressure and a temperature of 22.0°C.

$PV = nRT \quad n = \frac{PV}{RT} = \frac{(1.00\ \text{atm})(0.600\ \text{liter})}{(0.0821\ \text{l·atm/mole·K})(295\ \text{K})} = 0.025\ \text{mol} \times \frac{28\ \text{g}}{1\ \text{mole}} = \mathbf{0.694\ g}$

32. What is the density of a gas at STP that has a molar mass of 44.0 g/mol?

$M = \frac{DRT}{P} \quad D = \frac{MP}{RT} = \frac{(44.0\ \text{g/mol})(1\ \text{atm})}{(0.0821\ \text{l·atm/mole·K})(273\ \text{K})} = \mathbf{1.96\ g/l}$

33. What is the molar mass of a sample of gas that has a density of 1.09 g/l at 1.02 atm pressure and 25.0° C?

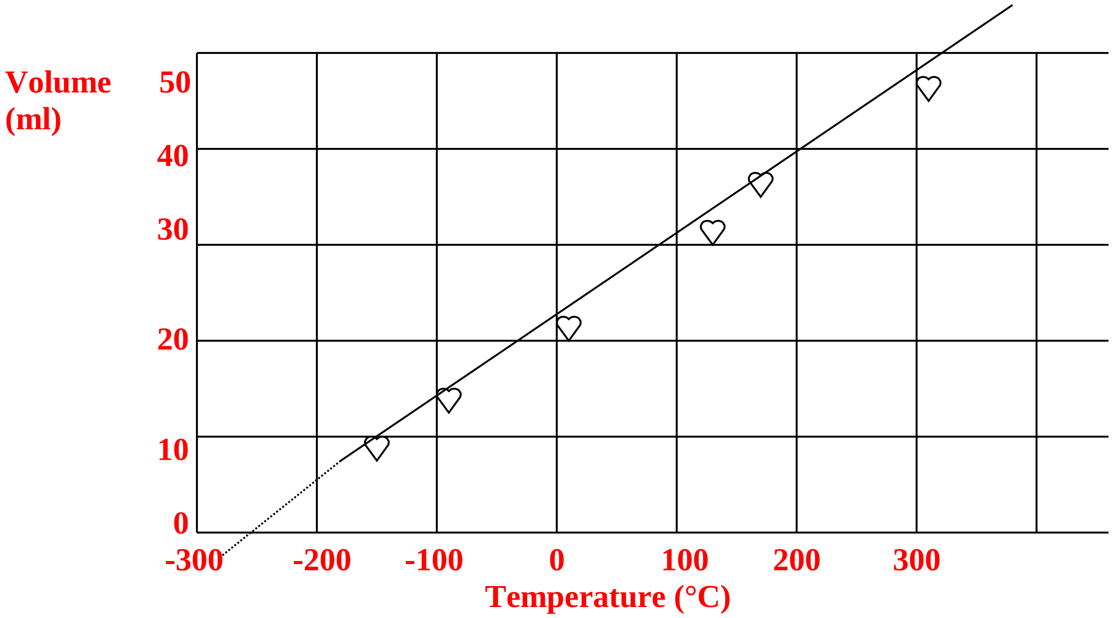
$M = \frac{DRT}{P} = \frac{(1.09\ \text{g/l})(0.821\ \text{l·atm/mole·K})(298\ \text{K})}{1.02\ \text{atm}} = \mathbf{26.11\ g/mol}$

34. Which of the following gases would you expect to behave most like an ideal gas at room temperature and atmospheric pressure: water vapor, carbon dioxide, helium or hydrogen? Explain.

Helium. The intermolecular forces are weaker in this gas as it is the smallest.

35. The data show the volume of hydrogen gas collected at a number of different temperatures. Illustrate these data with a graph and use them to determine the temperature at which the volume will reach a value of 0 ml. What is this temperature called? **Absolute zero**

| **Volume of $H_2$ collected at different temperatures** | | | | | | |
|---|---|---|---|---|---|---|
| **Trial** | 1 | 2 | 3 | 4 | 5 | 6 |
| **T (°C)** | 300 | 175 | 110 | 0 | -100 | -150 |
| **V (ml)** | 48 | 37 | 32 | 22 | 15 | 11 |



***Gas Stoichiometry***

36. Determine the volume of hydrogen gas needed to react completely with 5.00 liters of oxygen gas to form water. **$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$**

$$5.00 \text{ liters } O_2 \times \frac{2 \text{ moles } H_2}{1 \text{mole } O_2} = \mathbf{10.0 \text{ liters } H_2}$$

37. How many liters of propane gas ($C_3H_8$) will undergo complete combustion with 34.0 liters of oxygen gas? **$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$**

$$34.0 \text{ liters } O_2 \times \frac{1 \text{ mole } O_2}{22.4 \text{ liters } O_2} \times \frac{1 \text{ mole } C_3H_8}{5 \text{ moles } O_2} \times \frac{22.4 \text{ liters}}{1 \text{ mole}} = \mathbf{6.8 \text{ liters}}$$

38. Ammonium nitrate is a common ingredient in chemical fertilizers. Use the reaction shown to calculate the mass of solid ammonium nitrate that must be used to obtain 0.100 liter of dinitrogen oxide gas at STP. $NH_4NO_3(s) \rightarrow N_2O(g) + 2H_2O(g)$

$$0.10 \text{ liter } N_2O \times \frac{1 \text{ mole } N_2O}{22.4 \text{ liters}} \times \frac{1 \text{ mole } NH_4NO_3}{1 \text{ mole } N_2O} \times \frac{81 \text{ g } NH_4NO_3}{1 \text{ mole } NH_4NO_3} = \mathbf{0.36 \text{ grams } NH_4NO_3}$$

39. When iron rusts, it undergoes a reaction with oxygen to form iron (III) oxide.

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$$

Calculate the volume of oxygen gas at STP that is required to completely react with 52.0 g of iron.

$$52.0 \text{ g Fe} \times \frac{1 \text{mole Fe}}{55.8 \text{ g Fe}} \times \frac{3 \text{ mole } O_2}{4 \text{ mole Fe}} \times \frac{22.4 \text{ liters } O_2}{1 \text{ mole } O_2} = \mathbf{15.65 \text{ liters } O_2}$$

40. A 2.02 g sample of Al is reacted with an excess of HCl (aq) and the liberated hydrogen gas is collected over water at 26˚C at a barometric pressure of 752 torr. What is the volume of gas collected? Vapor pressure of water at 26˚C = 25.2 torr.

**$2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$**

$$2.02 \text{ g Al} \times \frac{1 \text{ mole Al}}{27 \text{ g Al}} \times \frac{3 \text{ mole } H_2}{2 \text{ mole Al}} = 0.112 \text{ mole } H_2$$

$$PV = nRT \Rightarrow V = \frac{nRT}{P} = \frac{(0.112 \text{ mole})(62.4 \text{ l-torr/mole-K})(299 \text{ K})}{(752-25.2 \text{ torr} = 726.8 \text{ torr})} = \mathbf{2.875 \text{ liters } H_2 \text{ gas}}$$