Review: Gaseous State

Why study gases ?
The importance of gases:
C_2H_2 – welding fuel
NH_3 – fertilizer
Ar – noble gas, Argon lamps
C_4H_{10} – lighter fluid
Cl_2 – disinfectant, bleach
N_2O – anesthetic
SO_2 – preservatives
etc...

1) Kinetic Molecular Theory
•particles in constant random motion
•expand to fill container (particles have no volume)
•large distances between particles
•*elastic collision* between walls of container and other particles (K_E conserved)
•no interactions, (i.e. no intemolecular attractive forces), among particles
•temperature is *proportionate* to the K_E of particles

2) Energy is stored in particles as:
•translations
•vibrations
•rotations
•electronic

3) Temperature of gas = measure of the average translation K_E of gas particles

Molecules move faster
Putting heat into a system (increase in temperature)
K_E ? $T = ½ m v^2$

4) Gases exert pressure P = F/A where F is N and A is m^2

1Pa = 1 N/m2 = 1 atm = 101.325 kPa
= 14.69 lb/in^2
= 1 bar = 100.00 kPa

5) Measuring gas pressure: using a Barometer = 760 mm Hg

1 atm = 101.325 kPa = 1 bar = 760 mm Hg = 760 torr

6) Liquids are <u>not</u> compressible but gases are.

P ? $1/V_{(gas)}$ and PV = constant (where n, T are kept constant)

i.e. 2 x P = 1/2 V or 4 x V = 1/4 P

Ex 1) $O_{2(g)}$ is placed in a cylinder, the volume it occupies is 50.0 L at a pressure of 109.5 kPa. What is the new pressure, P_2, at 25.0 ^oC? (Assume temperature is constant) (Use $P_1V_1 = P_2V_2$)

Ex 2) A balloon is filled with Helium gas. The volume of the gas is 20.0 L when it has a pressure on 99.9 kPa. The balloon is released at a higher altitude and the pressure decreases to 60.6 kPa, what is the volume of the balloon?

7) Gases expand with temperature.
Warmer air rises since it is less dense than colder air.

$V_{(gas)}$? T (where n, P are kept constant)

$$V_1/T_1 = V_2/T_2$$

Therefore if T is doubled then so is V.

$V_{(gas)} = 0$ @ T = 0 Kelvins = absolute zero (which has never been attained and never will be)

Ex 3) There is $O_{2(g)}$ in a cylinder, at 760 mm Hg, the volume it occupies is 1.00 L at a temperature of 25.0 ^oC. Calculate the volume of the gas when the cylinder is cooled to -196 ^oC. Assume pressure remains constant.

8) Avogadro

V ? the number of molecules (moles) of gas
@ at constant temperature and pressure

Therefore, we use **STP**

If n = 1 then 1 mol = molar volume of gas = 22.7 L/mol
9) Combined Gas Law

V? 1/P ? T ? n
V? nT/P

or

$$P_1V_1/n_1T_1 = P_2V_2/n_2T_2$$

Ex 4) A container holds 10 moles of a gas. At 90.0 ^oC the pressure is 95.0 kPa and it has a volume of 4.00 L. Calculate the pressure when the temperature is increased to 150 ^oC and the volume is 3.00 L

$V ? \; nT/P$

$PV/nT = R$

R = Universal Gas Constant (the same for all gases)

R = 0.08205 L.atm /mol.K = 8.314 J/mol.K

$PV/nT = R$ or $PV = nRT$ (ideal gas law)

Uses of PV = n RT Stoichiometry:

Ex 5) $CaCO_3 \rightarrow CaO + CO_{2(g)}$

10.00 Kg volume of CO_2?

@ 1000°C and 100.0 kPa

10) Use of PV = nRT to calculate:

(a) gas densities, (b) partial pressure (c) mole fraction, (d) molar mass of gas

(e) mass of gas

Ex 6) $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

If you have 2.80 L of CH_4 @ 25.0 °C and 120 kPa and 35.0 L of O_2 @ 31.0 °C and 96 kPa what is the volume of CO_2 @ 125 °C and 250 kPa?

(Note: This is a LR/XS type problem)

Ex 7) Calculate the molecular weight of a gas 0.1645 g that occupies 0.200 L @ 98.6 kPa and 289 K.

Ex 8) $D = m / V$ & $PV = nRT$ & $D = M_R P/RT$

Calculate the density of $CH_{4(g)}$ @ 25.0 °C and 101.5 kPa

Daltons Law of Partial Pressure

dry air + water vapour -> moist air

mixture of gases ($gas_1 + gas_2 + gas_3$...)

Total Pressure = $P_1 + P_2 + P_3$...

P_1 (partial pressure of gas) = $n_1/n_T \times P_T$ or n_1RT/V

n_T (mole fraction) = $n_1 / n_1 + n_2 + n_3$...

Measuring gas volumes

collect gases over H_2O

Total Pressure = collected gas + $H_2O_{(g)}$

$P_{Total} = P_{gas} + P_{vapour}$

Ex 9) $Al_{(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$

If 1.50 g of $Al_{(s)}$ and 25.0 cm^3 and 2.00 mol dm^{-3} of $HCl_{(aq)}$ are used @ 23.0 °C and 102.3 kPa, determine the volume of hydrogen gas collected.

(Note: This is a LR/XS type problem)

11) Non-ideal gases PV = nRT
Kinetic Molecular Theory assumed:
•molecules have no volume (but they do)
•molecules do not interact with one another (but they do)

gas: no interactions/higher K_E
raise P/or lower T gas --> liquid
liquid: lower K_E, stronger interactions because of the smaller distance between the molecules.

At High Pressure: molecules are now much closer together, and molecules are slower
Low T: attractive forces dominate
At high pressure and Low temperatures, ideal behaviour not observed.
Thus, modifications to PV = nRT required, as shown by van-der-Waals equation.

Review Questions

1. You have a 1.00 L flask of $NH_{3\,(g)}$ and a 1.00 L flask of $CO_{2\,(g)}$ both at 50.0 kPa and 25.0 EC.
   Compare the two flasks using terms such as #, $, or =.
   A) Average Velocity
   B) Average Kinetic Energy
   C) Number of Molecules
   D) Total Mass

2. $3\,CuO_{(s)} + 2\,NH_{3\,(g)} \longrightarrow 3\,H_2O_{(g)} + N_{2\,(g)} + 3\,Cu_{(s)}$

Calculate the volume of $N_{2\,(g)}$ that can be produced from 100.0 g of CuO, reacting with 20.0 mL of 1.00 mol/ L ammonia, at 22. 0 EC and 96.9 kPa .

3. a sample of nitrogen gas is collected over water. The total gas pressure is 98.9 kPa. The volume of the gas collected is 2.00 L at 30.0 EC. the vapour pressure of water at 30.0 EC is 4.24 kPa. What mass of nitrogen gas has been collected?

4. Calculate the density of helium gas at 23. 0 EC and 100.0 kPa.

5. Calculate the pressure exerted by 5.50 moles of hydrogen gas in a 150 L container at 50.0 0 EC.

6. Calculate the relative rates of effusion of hydrogen gas and helium gas.

7. Consider the following reaction:

$$4\,HCl_{(g)} + O_{2\,(g)} \longrightarrow 2\,H_2O_{(g)} + 2\,Cl_{2\,(g)}$$

If 100 L of $HCl_{(g)}$ is reacted with 100 L of $O_{2\,(g)}$, at the same temperature and the same pressure determine the volume of $Cl_{2\,(g)}$. Determine the volume of the excess gas remaining.