GASES

Name:

Table of Contents

1 – Properties of Gases

Measurable Properties of Gases

- Pressure
- Temperature
- Volume
- Amount (mass or moles)

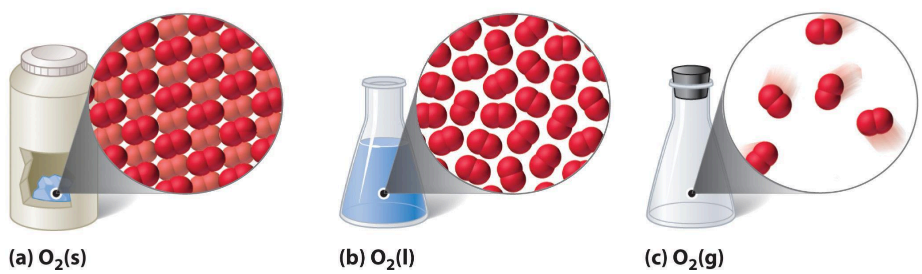
Pressure - the force per unit of area. Force is created by moving gas particles as they **<u>collide</u>** with each other and **<u>the walls of the container</u>**.

Density – the **<u>mass</u>** of an object per unit volume. Expressed as $d = \frac{m}{V}$.

Properties of Gases

All matter is made of particles

- These particles are constantly in motion
- Higher energy particles move faster than lower energy particles
- The particles in solids are closer together than in liquids, the particles in liquids are closer than in gases



- Gases are compressible
  - o Volume of a gas decreases when pressure is exerted on the gas. The volume of solids & liquids does not change under pressure.
- Gases expand as the temperature is increased under constant pressure.
  - o Volumes of solids & liquids increase with temperature but to a much smaller extent (negligible).
- Gases have smaller densities than solids and liquids
- Gases mix easily and completely when placed in a closed container. All gases are miscible (mix completely at any ratio)
- Gases have low resistance to flow (low viscosity) which allows them to escape quickly from small openings in containers.

Kinetic Molecular Theory

Developed to describe the behavior of gases using an **ideal gas**. No gas is ever ideal, the theory holds for gases at ordinary temperatures and pressures.

An ideal gas:

- Has molecules that are in constant, **random** motion, travelling in **straight lines** until they collide with one another or the **container**.
- Is a **point** mass, meaning that the mass takes up **no space** or has **volume**. This is because the volume of the container (empty space) is **significantly greater** than the volume of the **gas particle itself**.
- Molecules interact with one another and the container through **elastic** collisions.
- The molecules have no **attractive** or repulsive forces with one another.
- Does not change state with changes in **temperature** or **pressure**.

LAB EXERCISE 4.A

A Thought Experiment about Gas Properties

Imagine that you have five gas cylinders that have the volumes and temperatures listed in **Table 1** and contain the same mass of nitrogen gas. Complete the Analysis by proposing a hypothesis (with reasoning) to answer the Problem. In the Evaluation, identify any difficulties you had in answering the question, state how certain you are about your answer, and list some additional information you think you need to improve the certainty.

Purpose

The purpose of this exercise is to create a hypothesis based on differing gas properties.

Problem

What is the order of gas cylinders, from most likely to explode to least likely to explode?

Report Checklist

- ○ Purpose
- ○ Problem
- ○ Hypothesis
- ○ Prediction
- ○ Design
- ○ Materials
- ○ Procedure
- ○ Evidence
- ● Analysis
- ● Evaluation (1, 3)

Evidence

Table 1 Comparison of Nitrogen Gas Cylinders

Cylinder number	Volume (L)	Temperature (°C)
1	1.0	800
2	2.0	200
3	2.0	300
4	4.0	200
5	4.0	800

Practice

- ❑ Nelson Page 164 # 1
- ❑ Nelson Page 168 # 1

Extra practice

- ❑ Questions from MHR textbook (available online)

2 – Pressure & Boyle's Law

Units of Pressure

Example: Convert the following pressure measurements into the requested unit.

593 mm Hg into atmospheres	
1.42 atm into kPa	
4.903 kPa into mm Hg	
1.6841 bar into kPa	
4.327 bar to mm Hg	

Boyle's Law

As the pressure on a gas increases, the volume of the gas decreases proportionally, provided that the temperature and chemical amount (or moles) of gas remain constant. This relationship between pressure and volume is said to be inversely proportional.

Formula:

STP and SATP

- Standard temperature and pressure (STP): ________ kPa (or ______ atm) and ________ºC.
- Standard ambient temperature and pressure (SATP): ______ kPa and ______ ºC.

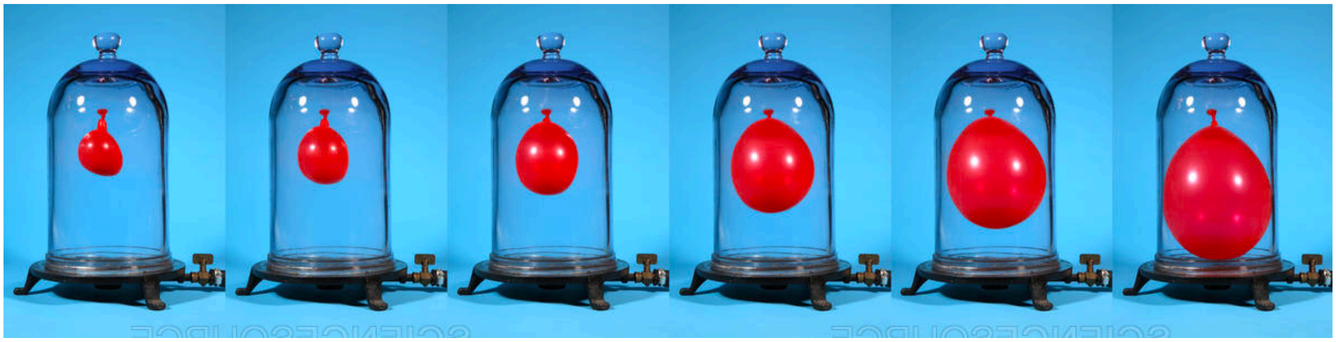
Example 1: A weather balloon with a volume of 2000 L at SATP rises to a height of 1000 m, where the atmospheric pressure is measured to be 60.8 kPa. Assuming there is no change in temperature, what is the final volume of the weather balloon?

Example 2: A 2.5 L sample of gas is trapped at 100 kPa in a cylinder with a moveable piston. If the pressure rises to 3.35 atm while the temperature is kept constant, what is the volume of the sample in the cylinder?

Example 3: A flexible container holds 4.0 L of air at 22 °C. If the temperature of the air remains constant, what will be the volume of the air if the pressure doubles?

<u>Kinetic Molecular Theory of Boyle's Law</u>

i.e. what's happening on a molecular level in the vacuum chamber?



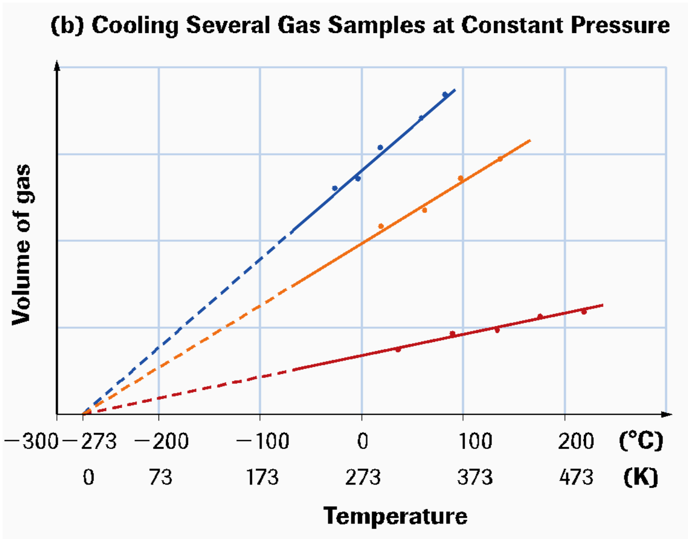
- Initially, the **<u>internal</u>** pressure (the balloon) and **<u>external</u>** pressure (the vacuum chamber) are the same (number of collisions inside and outside of the container are **<u>equal</u>**).
- When the external pressure is **<u>decreased</u>**, the volume of the balloon **increases**.
- This decreases the number of **<u>collisions</u>** of the molecules because they are further apart, therefore decreasing the internal pressure.
- The volume will continue to **<u>increase</u>** until the number of collisions inside the balloon (internal pressure) and outside of the balloon (external pressure) are **<u>equal</u>** again.

Practice
❏ Nelson Page 150 # 2, 4 ❏ Nelson Page 152 # 6, 7, 8, 9

3 – Temperature & Charles' Law

Kelvin Temperature Scale

Absolute Zero - theoretically the lowest possible temperature, or the temperature at which the volume of a gas is zero.



0 K = __________ ºC

Temperature conversion:

Formula:

Note: 0 is as low as you can go in K, there are no negative temperatures in Kelvin

Example: Convert the following temperature scales

0ºC to Kelvin	
22.0ºC to Kelvin	
524 K to degrees Celsius	
-163.592ºC to Kelvin	

Charles's Law

As the temperature of a gas increases, the volume increases proportionally, provided that the pressure and chemical amount (moles) remain constant. This relationship between temperature and volume is said to be directly proportional.

Formula:

Example 1: An inner tube is filled with 2000L of air in the hot Okanagan afternoon sun, at 36.5ºC. Alexandra decides to go tubing after dinner when the temperature has cooled to 18.3ºC. How much has the tube inflated/deflated with this change in temperature?

Example 2: A birthday balloon is filled with 5.00L of helium at 22.5ºC. The balloon is left outside overnight where the volume is measured at 4.75L. What was the overnight low in degrees Celsius?

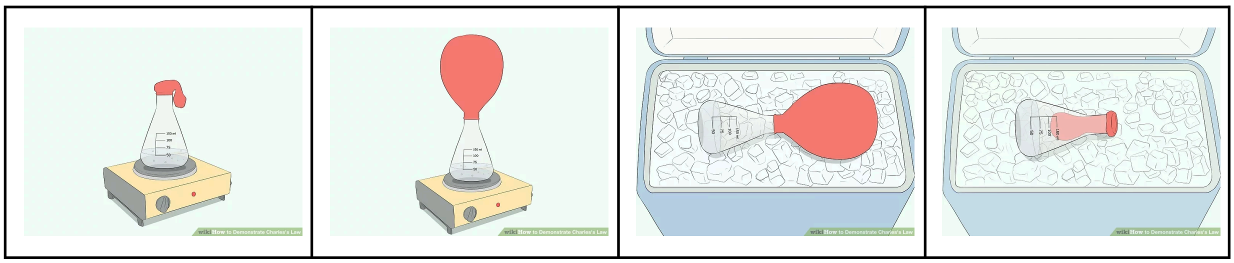
Example3: Which of the following is the best representation of Charles' Law?

A. If the Kelvin temperature of a quantity of gas is doubled and the pressure is held constant, by what factor is the volume changed?

B. If the Celsius temperature of a quantity of gas is tripled and the pressure is held constant, by what factor is the volume changed?

Kinetic Molecular Theory of Charles' Law

i.e. what's happening on a molecular level in the balloon when heated?



- Initially, the **internal** pressure and **external** pressure of the gas are the same (number of collisions inside and outside of the balloon are **equal**).
- As temperature increases, the molecules begin to move **faster** and have **more** collisions with each other and the walls of the balloon. This results in an **increase** in internal pressure.
- The internal pressure is now **more** than the external pressure, causing the balloon to **increase** in volume.
- As the volume increases, the number of collisions between molecules and the balloon **decrease** and the internal pressure begins to **decrease**.
- The balloon increases in volume until **internal** and **external** pressures are equal again. (i.e. the number of collisions inside and outside the balloon are equal).

Practice
❏ Nelson Page 154 # 12, 13 ❏ Nelson Page 156 # 14, 15, 16, 17

4 – The Combined Gas Law

Combining Boyle's and Charles' laws, the **combined gas law** produces a relationship between temperature, pressure and volume of a constant chemical amount (moles) of a gas.

Formula:

Example 1: If you were to take a volleyball scuba diving with you what would be its new volume if it started at the surface with a volume of 2.00L, under a pressure of 752.0 mmHg and a temperature of 20.0°C? On your dive you take it to a place where the pressure is 1943 mmHg, and the temperature is 2.45°C?

Example 2: A mountaineer climbs Mt. Everest and brings 0.750L of camp stove fuel (compressed gas canister) with a pressure of 4.00atm at 30°C? As she reaches the summit, she notices that the pressure in the canister has been decreased to 2.20 atm and the volume has increased to 1.15L. What is the temperature at the top?

Example 3: In a sample of gas, the temperature increases by a factor of 5 and the pressure halves. What is the change in the volume?

The combined gas law is a useful starting point for all cases involving pressure, volume and temperature, even if one of the variables is a constant. A variable that is constant can easily be eliminated from the combined gas law equation.

Example 4: A can of hairspray with a fixed volume contains a gas at a pressure of 352 kPa and a temperature of 20ºC. If the cylinder is heated to 50ºC, calculate the new pressure.

Practice

- ❏ Nelson Page 159 # 20, 21, 22, 23
- ❏ Nelson Page 161 # 6

5 – The Law of Combining Volumes

- When gases react, the volumes of the gaseous reactants and products, at the same temperature and pressure conditions are in whole-number ratios. i.e. the volume of one entity can be determined by using the mole-ratio (stoichiometry).
  - Scientists discovered that 100 mL of hydrogen and 50 mL of oxygen made 100 mL of water vapour, but these volumes didn't add up and they couldn't make sense of these ratios based on the molar mass of the compounds.
  - However, looking at the coefficients in the balanced chemical equation it can be determined that the ratios of moles and volume are the same.

Example 1: If the scientists had used 75 mL of hydrogen, what volume of oxygen would be required? And what volume of water vapour would be produced?

Example 2: A catalytic converter in the exhaust system of a car uses oxygen to convert carbon monoxide to carbon dioxide. If we assume constant temperature and pressure, what volume of oxygen is required to react with 125L of CO(g)? What would be the volume of each product produced?

Example 3: What volume of nitrogen gas forms when 150mL of ammonia decomposes into its elements?

Avogadro's Law

Equal volumes of gases at the same temperature and pressure contain the same number of molecules. (i.e. to have the same number of collisions, there must be the same number of molecules, or moles, present). It can be said that the volume of a gas is directly proportional to the number of moles of gas.

Formula:

Example 1: A student had a balloon that contained 1.24L of helium when she added 0.65mol of helium. If the student added an additional 0.50mol of gas, what will the volume of the balloon be, assuming constant pressure and temperature?

Practice

- ❏ Nelson Page 166: # 5, 6, 7
- ❏ Nelson Page 168: # 4ab, 5abcd

6 – Molar Volume

According to Avogadro when pressure and temperature are constant volume and the number of moles of gas present are proportional.

Formula:

Example 1: What chemical amount (number of moles) of propane is contained in a 20 lb tank (17.78L) if the gas is at SATP?

Example 2: An oxygen tank's mass decreases by 3.6 kg over the course of one day. What volume of oxygen at SATP was used that day?

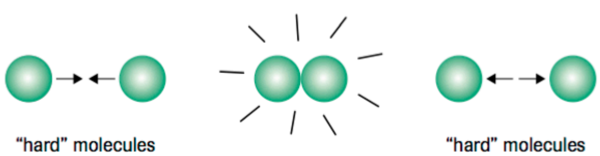
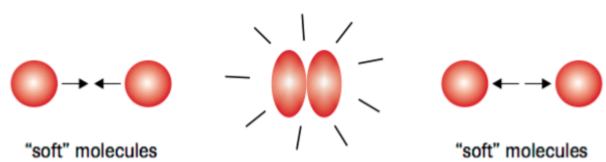
Practice
❏ Nelson Page 171 # 5, 7, 9, 11, 13

7 - The Ideal Gas Law

Remember.... An Ideal gas obeys all of the gas laws, perfectly under all conditions. **But in reality...**Real gases aren't all that ideal and don't always follow the kinetic molecular theory.

Gases deviate from ideal gas behavior at low temperatures and high pressures… why?

Kinetic Molecular Theory for….

IDEAL GASES	REAL GASES
• Point mass - takes up no space/volume but has mass ○ $V_{\text{empty space}} >> V_{\text{molecule}}$	• At very high pressures, the molecules of a gas become so tightly packed that their volume is significant compared to the overall volume
• Travel in straight, constant motion until they collide with something (container/one another) • The molecules have no attractive or repulsive forces with one another.	• As the temperature decreases, the molecules slow down & begin to have intermolecular attractions. • cause the molecules to stick together and the gas begins to take up less volume and eventually condenses to a liquid (NO LONGER A GAS!)
• Collide with elastic collisions 	• Shape change during collision and rebound makes this process occur a little more slowly & they lose energy reducing the force of collision, therefore reducing pressure. 

Example: Which of the noble gases will deviate from ideal gas behavior the most noticeably and why?

When are real gases most ideal? ____

Ideal Gas Law

Ideal Gas Law describes the relationship of pressure, temperature, volume and chemical amount of matter (the four variables that define a gas) into one equation.

Formula:

Example 1: Argon has many uses in refrigeration, lasers and light bulbs. Neon produces a red colour when subjected to high voltage which makes it, among other noble gases, useful in neon signs. What mass of neon gas should be introduced to an evacuated 0.88L tube to produce a pressure of 90 kPa at 30ºC?

Example 2: What volume does 50 kg of oxygen gas occupy in a gas tank at 50atm and 21.4℃?

Example 3: What is the density of argon at 20ºC and 98 kPa?

Practice

- ❏ Nelson Page 176 # 1, 2, 4, 5, 6, 7, 8, 9, 11, 12