SCH 3UI Unit 08 Outline: Kinetic Molecular Theory and the Gas Laws

Lesson	**Topics Covered**	**Handouts to Print**	**Homework Questions and Assignments**
1	**Note: The States of Matter** • solids, liquids and gases • state and the polarity of molecules • the Kinetic Molecular Theory of Matter (KMT) • types of molecular motion	The States of Matter Characteristics of Solids, Liquids and Gases	• Complete handout: Characteristics of Solids, Liquids and Gases • know the names of the changes of state
2	**Note: Temperature and the State of Matter** • definition of temperature • the Kelvin temperature scale • comparing the potential and kinetic energy of substances • energy changes during changes of state **Note: Pressure and the State of Matter** • definition of pressure • common units for pressure • conversions between pressure units	Temperature and the State of Matter Understanding Temperature, Pressure and the State of Matter A Heating Curve for Pure Water	• Complete handout: Understanding Temperature, Pressure and the State of Matter • Complete just the graphing portion of the handout: A Heating Curve for Pure Water. Bring the completed graph to our next class • visualize and UNDERSTAND what is happening to the particles when they are being heated or cooled and changing state
3	**The KMT Applied to Gases** • five points of the KMT for Gases • characteristics of an "Ideal Gas" **Note: The Gas Laws: Charles' Law** • the relationship between volume and temperature of a gas: graphically and mathematically • introduction to proportionality statements • derive Charles' Law mathematically • using Charles' Law	The Kinetic Molecular Theory Applied to Gases Charles' Law Practice Questions	• read, UNDERSTAND and answer the questions on handout: The Kinetic Molecular Theory Applied to Gases • Charles' Law Practice Questions
4	**Note: The Gas Laws: Boyle's Law** • the relationship between volume and pressure of a gas: graphically and mathematically • derive Boyle's Law mathematically • using Boyle's Law **Note: Gay-Lussac's Law** • the relationship between temperature and pressure of a gas: graphically and mathematically • proportionality statements • derive Gay-Lussac's Law mathematically • using Gay-Lussac's Law	Boyle's Law Practice Questions Gay-Lussac's Law Practice Questions	• Boyle's Law Practice Questions • Gay-Lussac's Law Questions • Moles of Gas (n) Practice Questions

SCH 3UI Unit 08 Outline: Kinetic Molecular Theory and the Gas Laws (continued)

5	**Note: The Combined Gas Law** • derive the Combined Gas Law • calculations using the Combined Gas Law	The Combined Gas Law Practice Questions	• The Combined Gas Law Practice Questions
6	**Note: The Ideal Gas Law** • calculating the Ideal Gas Law constant, R • values for R using different pressure units • calculations using the Ideal Gas Law	Ideal Gas Law Practice Questions	• Ideal Gas Law Practice Questions • begin Unit 8 Review: KMT, States of Matter and Gas Laws
7	**Lab #8** • Dalton's Law of Partial Pressures • prelab and lab	Lab #8 handed out in class	• begin lab report for lab #8 • complete Unit 8 Review: KMT, States of Matter and Gas Laws (in manual)
8	**Unit Test: KMT and the Gas Laws**		

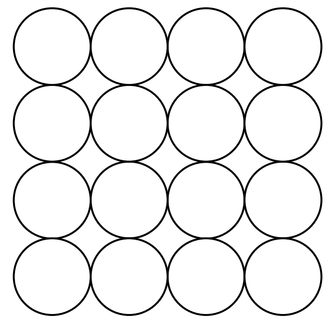
The States of Matter

The state of a substance at SATP (_______ and __________) is a _______________________ of that substance. For example, at SATP, H_2 is always a _______, H_2O is always a _________ and NaCl is always a __________.

The state of a substance at SATP depends on the ____________ of the _____________ ***between*** the particles in the substance, or the ____________________forces of attraction.

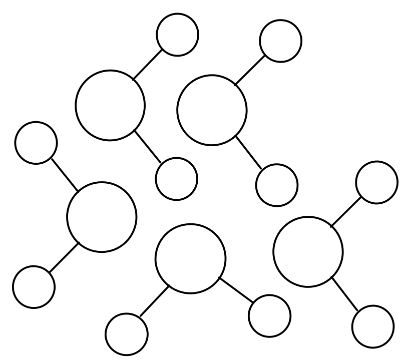
Solids have the following characteristics:

1. They have ___________________________ of inter-molecular attraction (the particles are _____________________________to each other). For example, all ionic compounds are _________________. They contain fully charged ________, which form a solid _______________________ at SATP.
2. The particles are _____________________________.
3. The particles in a solid are "____________________" and have ______________________________. Solids _________________.
4. Solids have a ________________________ and __________ ___________ the shape of their container.
5. Solids have a ____________________________________.
6. Solids _____________________________ under normal conditions.



Liquids have the following characteristics:

1. There are ____________________________ of inter-molecular attraction (the particles are __________________________ to each other), often by _______________________. Many _______________________ compounds are __________________________.
2. The particles are _______________________ (but not as close as the particles in a solid).
3. The particles in a liquid are _______________________. They can ___________________________________, so liquids __________________.
4. Liquids have _______________________. They take on the ______________________________________.
5. Liquids have a _______________________________.
6. Liquids ______________________________________ ________________ under normal conditions.

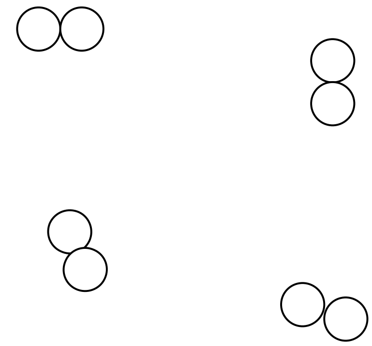


eg. Water is a _______________________ compound. There are _____________________ ____________ between the __________________________ positive and negative parts of the molecules. This is called "__________________________". Hydrogen bonding holds the molecules together tightly enough to be a ____________, but not tightly enough to be ____________. The molecules can ____.

Gases have the following characteristics:

1. There are ____________________________of inter-molecular attraction (the particles have ___________________________________ to each other).
2. The particles are ______________________.

3. The particles in a gas are ____________________________.
   They can ____
   and ____________________________.
4. Gases have ___________________________. They take on the
   ____.
5. Gases have _________________________. They will
   ____________ to take up whatever space is available.
6. Gases can _______________________________ under
   normal conditions.



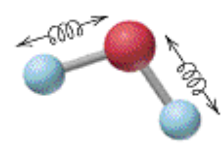
Because they have ____________________, pure covalent compounds have ________________ ______________________________________. Many pure covalent compounds are __________ _____________, for example; ____.

Because they can flow, both liquids and gases are ___________.

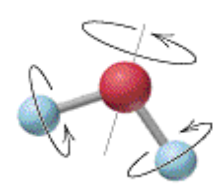
The States of Matter and Types of Molecular Motion

The Kinetic Molecular Theory of Matter (________) states that all matter is made up of ____________ (_________, ________ or __________________) and that these particles are in ___________________________. There are three different types of molecular motion:

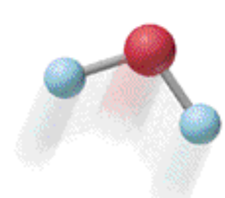
1. **<u>Vibrational motion</u>**: The particles in a substance ____________ (move _________ and __________) about a fixed point. For example, the atoms within a compound vibrate back and forth ____________________________.
   - vibration occurs in ____________, ____________ and ____________.
   - vibration is the only type of movement of the particles in ___________.



2. **<u>Rotational motion</u>**: The particles in a substance _________ or ____________ about a fixed axis, just like the ____________ on a _______.
   - the particles in a solid are "_________________________" by strong ____________________ attraction, so they _________________________.
   - the particles in _____________ and ____________ are free to move, so they _____________ as well as ______________. This is what allows liquids and gases _______________ (be ___________).



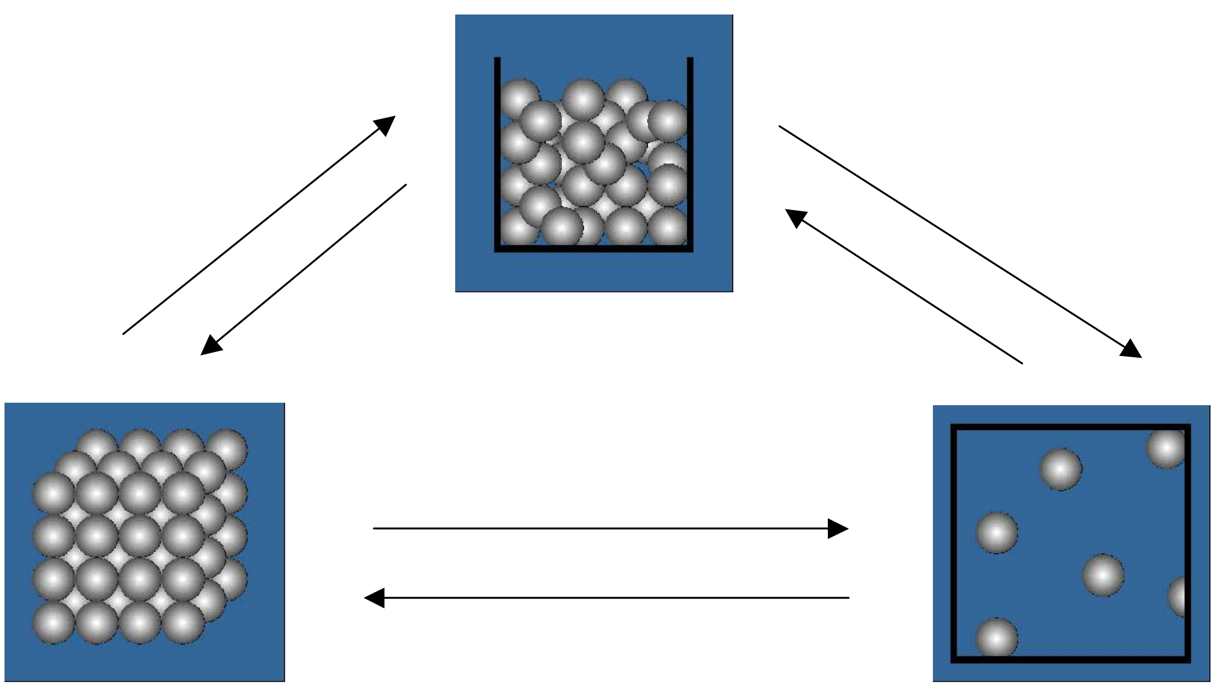
3. **<u>Translational motion</u>**: The particles in a substance can move from ____________ to ____________ (___________________).
   - the particles in a solid are "_________________________" by strong ____________________ attraction, so they _________________________.
   - The particles in a liquid have ___________ inter-molecular attraction so they can gradually move from __________ to ___________. Liquids have _____________ translational motion
   - The particles in a gas have ____________________ inter-molecular attraction, so they _______________________ and have _________ translational motion



Characteristics of Solids, Liquids and Gases

	Solids	Liquids	Gases
Describe the strength of attractive forces between particles.			
Describe the amount of space between particles.			
Can the particles in this state be compressed?			
Do the particles in this state have a definite shape?			
Do the particles in this state have a definite volume?			
Can the particles in this state flow (is this state a fluid)?			
Does the volume of this state increase when heated?			
Describe the types motion of particles in this state.			
Describe the relative potential energy of the particles.			

Study the following diagrams of the States of Matter. Label the names of the Changes of State between the different states.



Temperature and the State of Matter

The KMT states that the particles in matter are in __________________________. The energy that objects have because of their motion is called ______________ energy (   ).

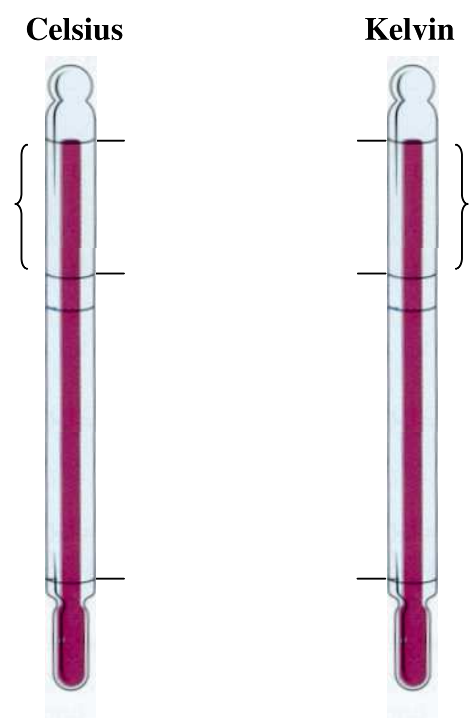
Temperature is defined as the _________________________________of the particles in a substance. That is, temperature tells us, on average, how ________ the particles in a substance are ____________. The higher the temperature, the __________ the particles are moving.

Temperature can be measured in ______. The ____________ scale is based on the __________ (____________) and ___________ points of _________: ______ and ________.

However, if temperature is supposed to measure ______________________________, then:

- there should be no such thing as ______________ temperatures, because there can not be __________________________ and
- ______ should mean __________________. But we know that the particles in a solid can ______________. That is _______ does not mean ______________________________.

There is another temperature scale called the _____________ (   ) scale. This is an ________ scale, so it does not need a _________ ( ) sign. ______ means ___________________________, which is known as ______________________________.
At ______, all motion _________ .

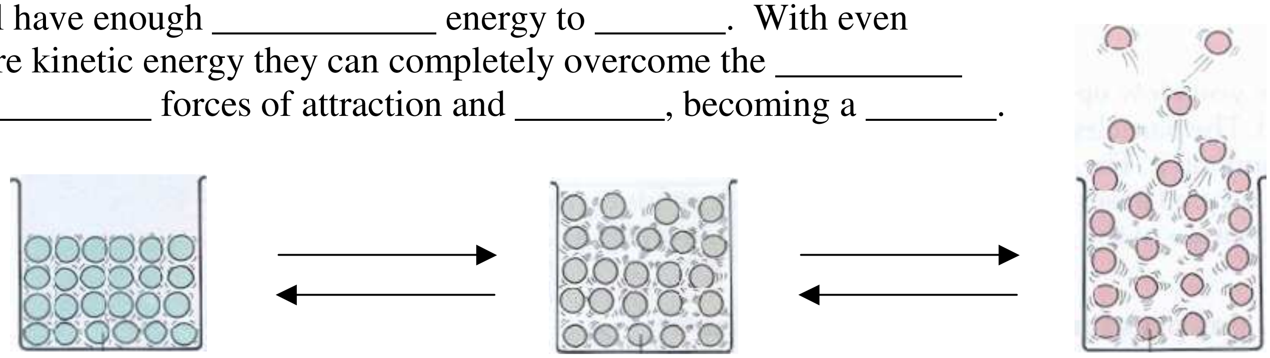


A Celsius degree and a Kelvin are the _________ ________. They only differ in the position of _________. ________ (_____________________) is equal to ____________.

eg. 25ºC =   37ºC =

> Any two substances with the same temperature have almost the same ____________________.

By changing the temperature of a substance, we can change its _________. As temperature increases, the particles move ___________ and ___________. At a certain temperature, they will have enough _____________ energy to ________. With even more kinetic energy they can completely overcome the ___________ ____________ forces of attraction and ________, becoming a _______.



When the state of a substance changes, its _____________ energy (   ) changes.

Recall: **Potential energy** is the energy that objects have because of their _____________ and _______________ to other objects.

The states of matter have different amounts of potential energy because of the ___________ ____________ the particles:

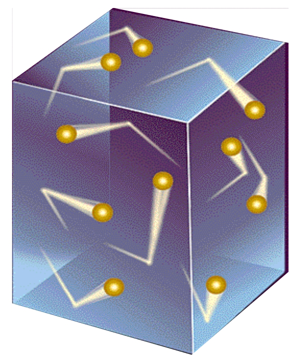
- the particles of a solid are __________________________, so E_p is _____________
- the particles in a liquid are a little _____________________, so their E_p is ________
- the particles in a gas are ___________________________, so their E_p is ______________

> The state of a substance tells us how much _______________ energy the particles have.
> The temperature of a substance tells how much ______________ energy the particles have.

eg. Compare the potential and kinetic energy of the following substances:molten iron at 1808K and helium gas at 298K.

	Molten Iron at 1808 K	**Solid NaCl at 966 K**	**Helium Gas at 37K**
Potential Energy			
Kinetic Energy			

Pressure and the State of Matter



Pressure is a measure of the ________ exerted on a certain ________ by the __________________________ with the surface of that area.

The more particles there are, and the higher their temperature (the _________ they are moving), the _____________ the pressure they can exert because they hit their container with more __________.

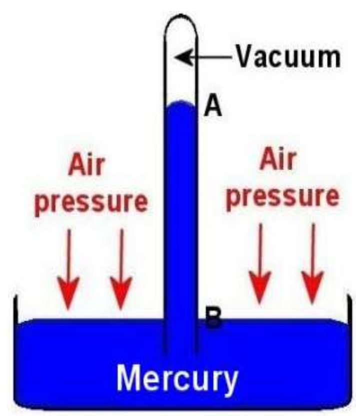
If the pressure on a gas is increased, the particles are squeezed _______________________, until they are close enough together to become a __________. With even more pressure, a liquid can be converted to a ________.

Similarly, decreasing pressure can convert a solid to a __________ and a liquid to a ______.

Standard (Air) Pressure is ________ kPa (_________________)
= ____
= ____
= ____
= ____

eg. convert 23.5 PSI to mmHg

eg. convert 1.35 atm to kPa



A Mercury Barometer
Invented by Torricelli.
A unit of pressure, the ***torr***, is named in his honour, where
760 *torr* = 760 mm Hg

Understanding Temperature, Pressure and the States of Matter

1. Carefully re-read the notes from the last two days. They contain a great deal of information.
2. In general, what determines the state of a substance at SATP?
3. Describe what happens to the particles of a substance during:
   a) evapouration (boiling)
   b) sublimation of a solid
   c) freezing
4. Define kinetic energy.
5. Define temperature. What does temperature tell us about the motion of the particles in a substance?
6. Explain why the Kelvin temperature scale must be used to describe molecular motion.
7. Convert between the following temperature units:
   a) 25ºC = ____________ Kelvins
   b) 25K = ______________ ºC
   c) 100ºC = ____________ Kelvins
   d) 0 K = ______________ ºC
   e) 0ºC = ____________ Kelvins
   f) 100K = ______________ ºC
8. Define potential energy.
9. Which state of matter has the lowest potential energy? Which state of matter has the highest?
10. Compare the potential and kinetic energies of the following substances:
    a) a piece of ice at -28ºC and a piece of ice at -1ºC
    b) a bottle of water vapour at 25ºC and a bottle of liquid water at 25ºC
    c) ammonia gas at 15ºC and ammonia liquid at -15ºC
11. Define pressure.
12. Convert between the following pressure units. Use the conversion factor method. Round your answer to the same number of significant digits as the original value.
    a) 2.25 atm to Torr
    b) 98.2 kPa to PSI
    c) 32 PSI to atm
    d) 155.4 kPa to mmHg
13. On the next page there are temperature vs. time data for a chunk of pure ice as it is heated from -18ºC to 130ºC. Carefully graph this data on a temperature vs time graph (time goes on the x-axis). Use a ruler to draw five (5) straight lines to “join the dots” and bring your completed graph to our next class.

The Kinetic Molecular Theory Applied to Gases

The Kinetic Molecular Theory is a set of statements which is used to explain the characteristics of the states of matter. The following additional statements apply specifically to the gaseous state.

1. Gases consist of small particles, either atoms or molecules depending on the substance, which are very far apart and their size is negligible (the particles themselves have essentially no volume).
2. Gas particles are in rapid and random, straight-line motion. The motion follows the normal laws of physics.
3. Collisions of the particles with the walls of their container or with other particles are PERFECTLY ELASTIC. This means that there is no loss of energy when particles collide.
4. There are essentially no attractive forces between gas particles.
5. The average kinetic energy of the particles is directly proportional to temperature. As the temperature of a gas is increased the particles move faster thereby increasing their kinetic (motion) energy.

To simplify the study of gases, scientists have defined an "Ideal Gas" as a gas in which:

1. Gas particles are so small that the particles themselves have no volume. This means that at absolute zero (0 K), when all motion stops, the volume occupied by the gas is zero.
2. The gas particles have zero attraction to each other (no inter-molecular attraction).

While neither of these assumptions is strictly true, they are acceptable approximations to predict the behaviour of gases under normal conditions of temperature and pressure.

Questions:

1. What type(s) of molecular motion do particles display when they are in the gas state? Describe each type of motion.

2. Use the points of the Kinetic Molecular Theory to explain the following characteristics of gases:
   a) Gases always fill their container.
   b) Gases are easily compressed.
   c) Gases mix readily with other gases.
   d) Gases diffuse. For example, the smell of ammonia gas gradually spreads throughout a room.
   e) Gases exert pressure.
   f) The pressure exerted by a gas increases as the temperature increases.

3. Students are sometimes asked to visualise gas particles as if they were 'billiard-balls' bouncing off each other and the sides of a pool table. Why is this not a completely accurate model of gas behaviour?

The Gas Laws: Charles' Law

There are four variables (factors) that affect the behaviour of gases:

1) ____________________________ 3) ____________________________

2) ____________________________ 4) ____________________________

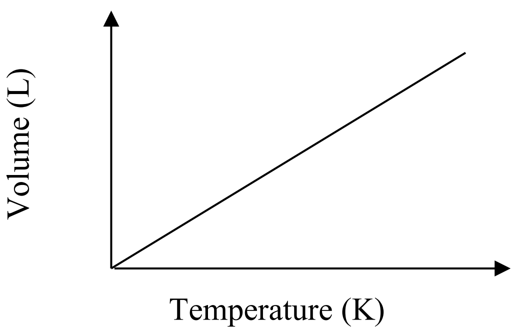
To be able to study the effects of each variable, we can consider only ____________________ at a time, while the other two must be ________________________.

Charles' Law is the relationship between ___________________ (in ____________) and the _________ of a gas, when the ________________ and _____________________________ of gas are held constant.

As the temperature of a gas increases, the volume will _______________ } This is called a
As the temperature of a gas decreases, the volume will _______________ } __________ relationship

We can write this as a __________________________ statement:
"   " means "_______________________________" or "_____________________________"

If we graph volume of a gas versus temperature (in Kelvins) we get a straight-line relationship:



The general equation for a straight line is _______________

For this graph:

- the "x" variable is __________________, ____
- the "y" variable is __________________, ____
- the y-intercept (b) is ________
- the slope (m) is ____________. In science, we use the letter _____ to represent a constant.

Re-writing the equation of the line using the above information, we get:

For any points on the line, there is a constant relationship:
eg.

If we rearrange these equations and solve for "k", we get:

Because "k" is constant, we can write the mathematical equation:

In words, Charles' Law states that the ______________ of a gas varies _____________with ____________________ (in   ) when _______________ and ________________ are held constant.

Using Charles' Law:
eg. A gas occupies 100 mL at 25 ºC. What volume will the same gas occupy at 150 ºC?

Homework: Charles' Law Questions in your manual and Graphing Assignment: Charles' Law

Charles' Law Practice Questions

1. Convert the following temperatures between ºC and Kelvins. Carry the same number of ***decimal places*** as the original measurement:
   a) 46.5 ºC = ____________ K
   b) 650 K = ___________ ºC
   c) -14 ºC = ____________ K
   d) 298.5 K = ____________ ºC

2. State Charles' Law in words. Be complete.
3. To study Charles' Law, which two variables must be held constant? Which two variables are changed?
4. Write Charles' Law as a proportionality statement (using the "α" sign)
5. Write Charles' Law as a mathematical expression.
6. A sample of gas occupies a volume of 250.0 mL at 25^{o}C. What volume will this gas occupy at 100^{o}C?
7. A sample of a gas is heated from 0 ^{o}C to 160 ^{o}C. The final volume is 18.0 L. What was the original volume?
8. 15.27 L of a gas at an unknown temperature is cooled to 60 ^{o}C. At this temperature, it occupies a volume of 8.44 L. What was the original temperature of the gas?
9. Calculate the volume in milliliters occupied by a gas at 35°C if it occupies 0.285L at 100.0°C. Assume constant pressure. (1 L = 1000 mL)
10. If the temperature of a gas (in Kelvins) is doubled, what happens to the volume of the gas?

Charles' Law Questions:

1a) 319.5 K b) 377ºC c) 259 K d) 25.5 ºC
6. 313 mL
7. 11.3 L
8. 602 K or 329ºC
9. 235 mL
10. the volume also doubles

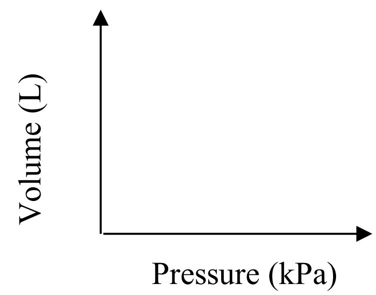
The Gas Laws: Boyle's Law

Boyle's Law is the relationship between pressure and the volume of a gas, when the number of moles and ______________________________ of gas are held constant.

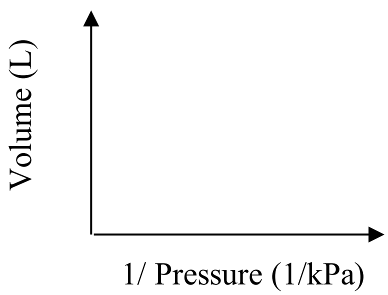
As the pressure of a gas increases, the volume will _______________ } This is called an ___________
As the pressure of a gas decreases, the volume will _______________ } or ____________ relationship

We can write this as a proportionality statement:
which is read "volume varies ___________ with ___________" or
"volume is __________________________________ to pressure"

If we graph volume of a gas versus pressure we get the following relationship:



However, if we graph volume versus the ___________ of pressure (   ), we get:



The general equation for a straight line is ___________

For this graph:

- the variable on the x-axis is __________________, ____
- the variable on the y-axis is __________________, ____
- the y-intercept (b) is ________
- the slope (m) is ____________. In science, we use the letter _____ to represent a constant.

Re-write the equation of the line using the above information and we get:

For any points on the line, there is a constant relationship:
eg.

If we rearrange these equations and solve for "k", we get:

Because "k" is constant, we can write:

In words, Boyle's Law states that the ______________ of a gas varies _____________ with ___________ when the ____________________ and ___________________________ are held constant.

eg. The air in a weather balloon has a volume of 40.0 L at 100.4 kPa pressure. What volume will the air in the balloon occupy at a pressure of 72.5 kPa?

Homework: Boyle's Law Questions in Gas Law Practice Questions
and finish the Simulation Lab: The Behaviour of Gases

Boyle's Law Practice Questions

1. There are several ways in which the pressure of a gas can be measured. Some of the units for gas pressure with their standard values are:
   - 101.3 kPa (kilopascals)
   - 760.0 mm Hg (millimetres of mercury)
   - 760.0 Torr
   - 1.00 atm (atmosphere)
   - 15.00 PSI (pounds per square inch)

   Using the fact that these are all equivalent values (all are measures of average air pressure at sea level), make the following conversions. Report the same number of significant digits as are in the original measurement. Refer back to the notes for lesson #2 if you do not remember how to do this.

   a) 550 Torr = _______________ kPa
   b) 95.9 kPa = _______________ atm
   c) 3.0 atm = ________________ PSI
   d) 1.00 kPa = ____________ Torr
   e) 266 atm = _____________ kPa
   f) 19.2 PSI = _____________ mmHg

2. State Boyle's Law in words. Be complete.
3. To study Boyle's Law, which two variables were held constant? Which two variables are changed?
4. Write Boyle's Law as a proportionality statement (using the "$\propto$" sign).
5. Write Boyle's Law as a mathematical expression.
6. The barrel of a bicycle pump can compress air from 1.2 atm to 6.0 atm. If the volume of the air before compression is 16.0 L, what is the volume of the air after it has been compressed?
7. A weather balloon containing 35.0 L of helium at 98.0 kPa is released and rises. Assuming that temperature is constant, what is the volume of the balloon when the atmospheric pressure is 25.0 kPa?
8. A small canister (tank) of oxygen gas contains 500.0 mL of gas at a pressure of 3.00 atm. The gas is released and captured in a large balloon, which expands to a final volume of 1.44 L. What is the pressure of the gas in the balloon?
9. A 6.75 L sample of nitrogen at 1140 torr is allowed to expand to 13.0 L. The temperature remains constant. What is the final pressure in atmospheres?
10. The pressure on a gas is doubled. What happens to the volume of the gas?

Boyle's Law Questions:

1a) 73 kPa b) 0.947 atm c) 45 PSI
1d) 7.50 Torr e) 2.69×10^4 kPa f) 973 mmHg

6. 3.2 L
7. 137 L
8. 1.04 atm
9. 592 Torr or 0.779 atm
10. the volume is halved

Gay-Lussac's Law Practice Questions

1. State Gay-Lussac's Law in words. Be complete.
2. To study Gay-Lussac's Law, which two variables were held constant? Which two variables are changed?
3. Write Gay-Lussac's Law as a proportionality statement (using the "α" sign).
4. Write Gay-Lussac's Law as a mathematical expression.
5. A woman has filled her car tires on a hot summer day (27 ºC) to a pressure of 220 kPa. The tires are cooled during the first cold winter night to –10 ºC.

a) Assuming that the tires have not lost any air, what is the air pressure in the car tires at this time?

b) If she measures the tires' air pressure with a tire gauge in PSI, what would it read in the winter?

6. A student is leaving to play a soccer tournament in Florida in December. She goes out to the garage on a –12 ºC day and fills her soccer ball to the regulation 8.00 PSI final pressure. When she gets to Florida, the temperature is 32 ºC. The ball will rupture if the internal pressure goes over 10 PSI. Will the soccer ball rupture?
7. A sample of a gas is collected at 35.0°C and 0.95atm. What would the pressure of the gas be at standard temperature (0°C), in atmospheres?
8. A sample of gas has its temperature (in K) doubled. What will happen to the pressure of the gas?

Moles of Gas (n) Practice Questions

1. As the number of moles of a gas increases, what will happen to the pressure exerted by the gas?
2. What variables must be held constant to study the relationship between moles of gas and pressure?
3. Write the relationship between moles of gas and pressure as a proportionality statement.
4. Write the relationship between moles of gas and pressure as a mathematical expression.
5. If 4.55 mol of argon gas exerts a pressure of 367.2 kPa, what pressure will be exerted by 2.50 mol of argon under the same conditions?
6. Write the relationship between moles and volume of a gas as a proportionality statement and as a mathematical expression. What variables must be held constant for these expressions to be true?
7. If 4.50 moles of a gas occupies a volume of 100.0 L, what is the volume of 2.00 moles of the same gas under the same conditions?
8. What is the volume of one mole of any gas at STP (from the moles unit)?
9. What is the mathematical relationship between number of moles of a gas and its volume at STP (from the moles unit)?
10. An unknown HOBrFINCl gas at STP occupies 19.7 L and has a mass of 24.64 g. What is the molar mass of this gas? What is its likely identity?

Gay-Lussac's Law Questions:	**Moles of Gas Practice Questions**
5a) 193 kPa b) 28.6 PSI	5. 202 kPa
6. 9.35 PSI, No the ball will not rupture	7. 44.4 L
7. 0.84 atm	8. 22.4 L/mol
8. the pressure also doubles	9. V = n x 22.4 L/mol
	10. 28.02 g/mol, the gas is probably N_2

The Combined Gas Law

So far, we have seen:

Avogadro's Law:

Charles' Law:

Boyle's Law:

Gay-Lussac's Law:

We can combine these gas laws into one big, beautiful equation called the ____________________________. This equation allows us to work with gases when ___________________ of the variables that affect the behaviour of gases are being changed at the ________________________.

Ex. A weather balloon is filled to a volume of 50.0L at 99.2 kPa and -3.6 °C. It rises and the temperature falls to -52.1°C and the pressure drops to 72.3 kPa. Calculate the new volume of the balloon.

Ex. A container holds 16.0 g of O_2 gas at a temperature of 25.0°C and pressure of 780.0 mmHg. Its volume is 11.9L. What mass of oxygen gas would you need to occupy a volume of 22.5L at 100.0°C and 800.0 mmHg?

Ex. A sample of neon gas is placed in a 2.50L balloon. Half of the gas is removed, the pressure is halved and the temperature (in Kelvin) is quadrupled. Calculate the new volume of the gas.

The Combined Gas Law Practice Questions

1. A 200.0 mL sample of gas is collected at 50.0 kPa and 217ºC. What volume would this gas occupy at 100.0 kPa and 0ºC?

2. A welder needs 5000.0 L of oxygen gas at 150.0 kPa pressure and 21ºC. To what pressure must a 50.0 L tank be filled at 13ºC?

3. Natural gas is usually stored in underground reservoirs or in above-ground tanks. A supply of natural gas is stored in an underground reservoir with a volume of 8.0 x 10^5 m^3 at a pressure of 360 kPa and temperature of 16ºC. It is then transferred to above-ground tanks at 120 kPa and 6ºC.

a) What is the volume of the gas when it is above ground?

b) The volume of each above-ground tank is 2.7 x 10^4 m^3. How many of these tanks will be required to hold ALL of the gas?

4. The vapourized fuel in the cylinder of diesel engine occupies 1.0 L at 24ºC and 101.3 kPa. As the engine operates, the fuel is compressed to 0.0714 L at 480ºC. What is the pressure in the cylinder under these conditions?

5. A weather balloon with a volume of 55.0 L is filled with hydrogen gas at a pressure of 98.5 kPa and a temperature of 13ºC. When the balloon is released it rises to the stratosphere where the temperature is -48ºC and the pressure is 19.7 kPa. What is the volume of the balloon in the stratosphere?

6. A 6.00 L sample of gas has its pressure tripled, the temperature halved and the number of moles quadrupled. What is the new volume of the gas? (hint: you can choose any initial values for the pressure, temperature and number of moles- then adjust them according to the question).

Answers

1. 55.7 mL
2. 1.46 x 10^4 kPa

3a) 2.3 x 10^6 m^3

3b) 86 tanks to hold all the gas

4. 3597.1 kPa = 3.6 x 10^3 kPa
5. 216 L
6. 4.00 L

The Ideal Gas Law

The Combined Gas Law equation is:

Recall from the mole calculations: one mole of any gas at STP (___________ kPa and _____°C) has a volume of ____________.

We can substitute these values into one side of the Combined Gas Law:

P_1 =

V_1 =

n_1 =

T_1 =

So we can re-write the Combined Gas Law Equation by substituting 'R' for one side of the equation:

'R' is the Ideal (aka Universal) Gas Law _______________. It is a constant, but its value depends on which unit is used to measure _________________:

- for pressure in kPa, the value of R is _____________
- for pressure in atm, standard pressure is 1.00 atm so R =
- for pressure in mmHg, standard pressure is 760.0 mmHg so R =
- for pressure in PSI, standard pressure is 15.0 PSI so R =

If you are given a gas law problem with _________ values for any of the variables (eg. two _____________, _______________________, ________________ or number of _____________), you must use the _________________ Gas Law equation to solve the problem:

If you are given a gas law problem with only _______ value for each of the variables (eg. one ___________, ______________________, ______________ and number of ___________), you must use the ____________ Gas Law equation to solve the problem. Make sure you use the value of 'R' that is appropriate for the ______________ units in the question.

eg. Calculate the volume occupied by 18.3 g of methane gas (CH_4) at a temperature of 78.2°C and 2.36 atm pressure.

eg. A 20.0 L flask contains 56.0 grams of nitrogen gas at -73°C. What is the pressure exerted by the gas in mmHg?

Ideal Gas Law Practice Questions

1. What is the volume of 0.25 grams of oxygen gas, O_2, measured at 25°C and 100.0 kPa?

2. A 5.0 L tank contains hydrogen, H_2. The temperature is 0°C and the pressure is 1.0 atm.
   a) How many moles of hydrogen gas are present?
   b) How many grams of hydrogen are present?

3. At what Celsius temperature will 10.0 grams of ammonia, NH_3, exert 700.0 mmHg pressure in an 8.0 L container?

4. Calculate the volume of 1.00 mol of chlorine gas, Cl_2, at STP.

5. Pounds per square inch is a commonly used pressure unit. The standard value is 15.0 PSI. What value of the ideal gas constant, R, must be used with this unit? (Hint: Substitute standard values for all the other variables into the ideal gas law.)

6. The volume of air in room 219 is about 140,000 L. How many "air molecules" are there in the room at 22°C and 100.0 kPa?

7. 2.40 g of a gas occupy a volume of 2.80 L at 180°C and 0.500 atm. Calculate the molar mass of the gas.

8. What volume would 1.3×10^{22} gas molecules occupy at 27°C and 304 kPa?

9. The density of a gas is 1.35 g/L at standard temperature and pressure (STP). What is the molar mass of the gas at STP?

10. A certain gas occupies 2.00 L. What volume will the gas occupy if the pressure is doubled, the Kelvin temperature is tripled and half the molecules escape? Hint: Use the combined Gas Law.

Answers:

1. 0.19 L
2a) 0.22 mol b) 0.44 g
3. -120°C
4. 22.4 L
5. 1.23
6. 3.4×10^{27} molecules
7. 63.8 g/mol
8. 0.18 L
9. 30.2 g/mol
10. 1.50 L