CHEMISTRY 30S

The Alchemist's Cookbook

UNIT 4 – LIQUIDS & GASES

NAME:______________________________________

It is expected that the activities in this book are completed as they are performed in class. This book will be collected at the end of the unit and a mark will be given.

LET'S GET STARTED!

By the end of this unit, you should be able to:

- ✓ Use the Kinetic Molecular Theory to explain properties of solids, liquids, and gases and the phase changes that happen between them.
- ✓ Explain the role of intermolecular forces in states of matter and volatility in phase changes.
- ✓ Explain vapour pressure and how it relates to boiling point of a substance.
- ✓ Define normal boiling point temperature of a liquid in terms of vapour pressure and atmospheric pressure.
- ✓ Obtain vapour pressure and boiling point temperatures of various substances from vapour pressure curves.
- ✓ Explain the concept of pressure using Kinetic Molecular Theory.
- ✓ Explain the concept of atmospheric pressure and provide situations in life where it affects you.
- ✓ Develop relationships between the pressure, volume, temperature, and amount of a gas (Boyle's Law, Charles' Law, Guy-Lussac's Law, Avogadro's Law)
- ✓ Use the Combined Gas Law and the Ideal Gas Law to solve problems involving the relationships among the pressure, temperature, and volume of a gas.
- ✓ Perform stoichiometric calculations on chemical reactions involving gases using ideal gas law and molar volumes.

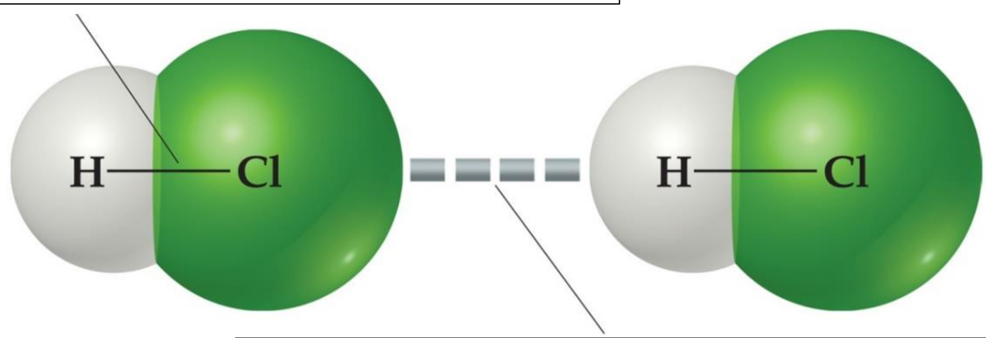
ACTIVITY #1 – WHAT DO YOU KNOW?

1. Circle the word(s) in each box that best describes the properties of the particles in each state of matter.

	SOLIDS	**LIQUIDS**	**GASES**
Types of motion exhibited by particles	*Vibrational* *Rotational* *Translational*	*Vibrational* *Rotational* *Translational*	*Vibrational* *Rotational* *Translational*
Strength of attraction between particles	*High* *Medium* *Low*	*High* *Medium* *Low*	*High* *Medium* *Low*
Organization of particles	*High* *Medium* *Low*	*High* *Medium* *Low*	*High* *Medium* *Low*
Amount of kinetic energy found in particles	*High* *Medium* *Low*	*High* *Medium* *Low*	*High* *Medium* *Low*

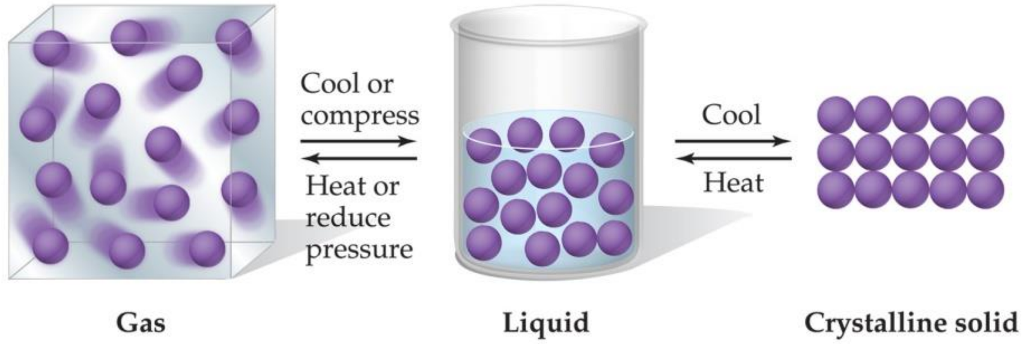
2. Circle the term(s) in each box that best describes the bonds indicated.

Type of Bond:	*Intramolecular/Intermolecular*
Relative Strength of Bond:	*Strong/Weak*
Example of Bond:	*Ionic/Covalent/Dipole-Dipole*



Type of Bond:	*Intramolecular/Intermolecular*
Relative Strength of Bond:	*Strong/Weak*
Example of Bond:	*Ionic/Covalent/Dipole-Dipole*

3. Circle the terms in each of the following statements to make them true.



a. As a substance **<u>cools</u>**, particles become (more/less) organized as they (gain/lose) kinetic energy. This causes the particles to (speed up/slow down). Intermolecular attractions between particles (strengthen and form/weaken and break). This allows the substance to begin changing state and become more like a (solid/gas).

b. As a substance **<u>warms</u>**, particles become (more/less) organized as they (gain/lose) kinetic energy. This causes the particles to (speed up/slow down). Intermolecular attractions between particles (strengthen and form/weaken and break). This allows the substance to begin changing state and become more like a (solid/gas).

<u>Answer the following questions in the space provided.</u>

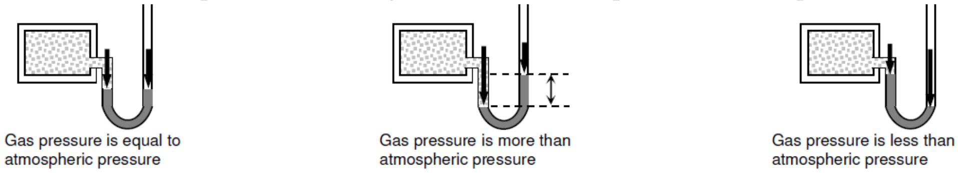
4. Are there larger attractive forces between molecules of gases, liquids, or solids? Explain.

5. What factor, in addition to strength of intermolecular attractions, affects the state of a substance? Explain how this factor affects the state.

6. What term means "the energy of motion"? What is an average measure of this "energy of motion"?

ACTIVITY #2 – MANOMETERS

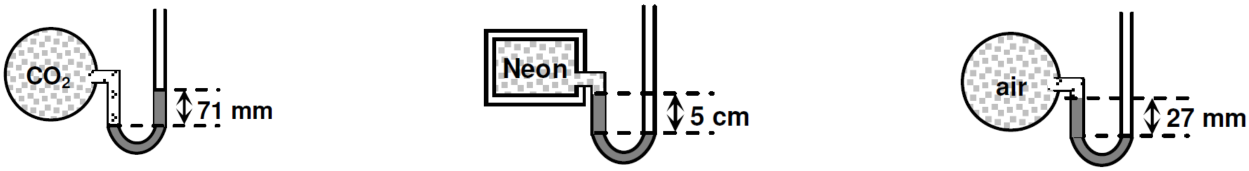
A manometer is a device that measures the pressure of a gas in a closed container. Many times the gas is produced by a volatile liquid (one that evaporates readily at low temperatures). A manometer is made from a U-shaped tube filled with mercury. The pressure of the gas in the container is compared to the pressure exerted on the mercury from the atmosphere. If the gas pressure is the same as the atmospheric pressure the level of mercury on both sides of the tube will be the same. If the gas has a higher pressure than the atmosphere, the mercury level on the side open to the atmosphere will be higher. If the gas is at a lower pressure than the atmosphere, the mercury level on the side open to the atmosphere will be lower, as shown below.



Solve each of the following problems:

1. What is the pressure of each of the gases in the manometers shown below?

P_{atm} = 760 mmHg P_{atm} = 745 mmHg P_{atm} = 765 mmHg



2. Fill in the following chart.

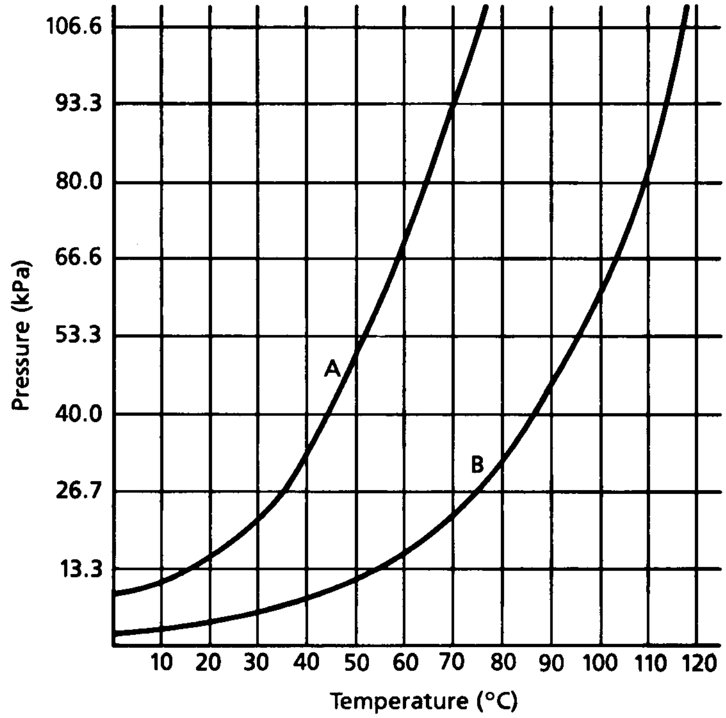
Gas Identity	Atmospheric Pressure (mm Hg)	Which side is higher?	By How Much? (mm)	Pressure of Gas (mm Hg)
oxygen	775	Gas	18	
nitrogen		Atmosphere	7.0	757
carbon monoxide	760		12	748
methanol	735	Atmosphere		755

3. A container of helium is connected to a manometer and the mercury level becomes 145 mm lower on the side open to the atmosphere. Atmospheric pressure is 775 mm Hg. What is the pressure exerted by the helium?

4. A basketball is attached to a manometer and the mercury is 18 mm higher on the side open to the atmosphere. If the atmospheric pressure is 748 mm Hg, what is the air pressure in the basketball?

ACTIVITY #3 – VAPOUR PRESSURE CURVES

The following graph shows vapor pressure curves for two substances, **A** and **B**:



1. What is the vapor pressure of **A** at 35°C?
2. What is the vapor pressure of **B** at 35°C?
3. At what temperature is the vapor pressure of **A** equal to 106.6 kPa?
4. What is the vapor pressure of **B** at this temperature?
5. At what temperature is the vapor pressure of **B** equal to 106.6 kPa?
6. What is meant by "normal boiling point"?
7. What is the normal boiling point of **A**?
8. What is the normal boiling point of **B**?
9. At what temperature would **A** boil if atmospheric pressure were 93.3 kPa?
10. What would the atmospheric pressure have to be in order for **B** to boil at the temperature you gave as your answer to Question 9?

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

ACTIVITY #4 – THE PRESSURE IS ON!

In class, you observed some of the effects that atmospheric pressure change has on the boiling point of a liquid as well as how it affects the volume of a gas.

In the space below each demonstration, list the observations you made during the demonstration and write a paragraph explaining your observations in terms of Kinetic Molecular Theory.

Demonstration #1 – Boiling Water with No Heat…

Observations:

Explanation:

Demonstration #2 – Vacuum Packing a Human

Observations:

Explanation:

ACTIVITY #5 – PRESSURE CONVERSIONS

1 atm = 760 mmHg = 760 torr = 101.3 kPa = 14.7 psi

Example:

What is 515 mmHg in kPa? 515 mmHg x $\frac{101.3 kPa}{760 mmHg}$ = 68.6440789 kPa = 68.4 kPa

Problems:

745 mmHg into psi

522 torr into kPa

727 mmHg into kPa

1.10 atm into psi

52.5 kPa into atm

800. mmHg into atm

0.729 atm into mmHg

125 kPa into torr

ACTIVITY #6 – PROPORTIONALITY

Say you are planning a small party at which you are going to serve pizza. You decide to purchase the pizza by the slice. You plan on buying **24 slices of pizza** in the hopes that that is how many people show up. It costs **$1 per slice** to buy the pizza.

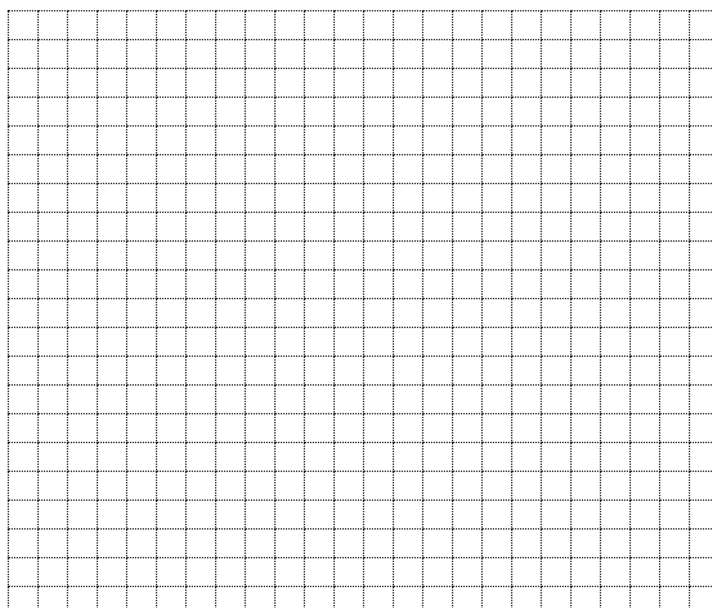
Fill in this chart of # of people and how many slices each person gets & construct a line graph of your findings.

# guests that show up	**slices per guest**
1	
2	
3	
4	
6	
8	
12	
24	

# of guests

1. Fill in this chart of # of slices and how much it would cost & construct a line graph of your findings.

# slices	**cost of pizza**
1	$ 1.00
2	
3	
4	
6	
8	
12	
24	



# of slices

Question:

One of these graphs is an example of variables that are "directly proportional" and the other is an example of variables that are "inversely proportional". Which is which? Justify your answer.

ACTIVITY #7 – LAB: AN INTRODUCTION TO BOYLES' LAW

Questions:
1. How do the **Pressure** and **Volume** of a gas relate to each other?
2. Can we find a ***mathematical relationship*** between the two variables?

Materials: Labquest data collection unit with gas syringe

Procedure:

1. Disconnect the syringe from the gas pressure sensor and set the plunger in the syringe to 10.0 mL. Reconnect the syringe to the sensor (not TOO tight). The pressure reads: ________ kPa.

3. Push the plunger in the syringe to 5.0. The pressure __________ (increases / decreases). Record the gas pressure in the chart below.

4. Repeat procedure with the other volumes to fill the data table.

Observations & Data:

Trial #	Pressure (kPa)	Volume (mL)	Actual Volume (mL)	Constant
1		5.0	5.8	
2		7.5		
3		10.0		
4		12.5		
5		15.0		
6		17.5		
7		20.0		

Calculations:

1. There is a correction we need to make. Inside the "Gas Pressure Sensor" there is a chamber that has a volume of 0.8 mL. So, the actual volume is not 5.0 mL, it is 5.8 mL. Fill in the Actual Volume column and use actual volume for future calculations.

2. Graph the data placing Actual Volume (mL) along the "x" axis and Pressure (kPa) on the "y" axis.

Questions:

1. The two variables, pressure and volume are changing during this experiment. What are the two variables that remain **constant** during the experiment?

___________________________ and ___________________________

2. From your graph, what kind of mathematical relationship exists between the pressure and volume of your gas?

Directly Proportional or Inversely Proportional

3. If the variables are ***directly*** proportional, the mathematical relationship is: P = kV or P/V = constant. If the variables are ***inversely*** proportional, the relationship is: P = k(1/V) or P·V = constant.

Choose which relationship should be correct and calculate the constant for your seven trials of data using Pressure and **Actual** Volume. Include the answers in your Data/Calculation Table.

Are the values pretty close? (compare the first two digits). _____

4. Make a graph of Pressure vs. $\frac{1}{Actual\ Volume}$.

Trial #	Pressure (kPa)	Actual Volume (mL)	$\frac{\mathbf{1}}{\mathbf{Actual\ Volume}}$ (mL^{-1})
1		5.8	
2			
3			
4			
5			
6			
7			

5. From your graph, what kind of mathematical relationship exists between the pressure and $\frac{1}{Actual\ Volume}$ of your gas?

Directly Proportional or Inversely Proportional

ACTIVITY #8 – PRESSURE VS. VOLUME…

In class, you observed some of the effects that pressure change has on the volume of a gas. Two of the examples demonstrated a gas law referred to as Boyles' Law. This law describes the relationship between volume of a gas and gas pressure.

In the space below each demonstration, list the observations you made during the demonstration and write a paragraph explaining your observations in terms of Kinetic Molecular Theory.

Demonstration #1 – We All Live in a Mini-Submarine…

Observations:

Explanation:

Demonstration #2 – Balloon vs. Vacuum Pump

Observations:

Explanation: (Hint…you need to take into account the atmospheric pressure for this one!)

ACTIVITY #9 – BOYLES' LAW PROBLEM SET

Boyle's Law states that the volume of a gas varies inversely with its pressure if temperature is held constant. (If one goes up, the other goes down.) We use the formula:

$$P_1 \times V_1 = P_2 \times V_2$$

Solve the following problems (assuming constant temperature). Assume all number are 3 significant figures.

1. A sample of oxygen gas occupies a volume of 250 mL at 740 torr pressure. What volume will it occupy at 800 torr pressure?

2. A sample of carbon dioxide occupies a volume of 3.50 Liters at 125 kPa pressure. What pressure would the gas exert if the volume was decreased to 2.00 liters?

3. A 2.00-Liter container of nitrogen had a pressure of 3.20 atm. What volume would be necessary to decrease the pressure to 1.00 atm?

4. Ammonia gas occupies a volume of 450 mL as a pressure of 720 mmHg. What volume will it occupy at standard pressure (760 mmHg)?

5. A 175 mL sample of neon had its pressure changed from 75.0 kPa to 150 kPa. What is its new volume?

6. A sample of hydrogen at 1.50 atm had its pressure decreased to 0.50 atm producing a new volume of 750 mL. What was the sample's original volume?

7. Chlorine gas occupies a volume of 1.20 liters at 720 torr pressure. What volume will it occupy at 1 atm pressure?

8. Fluorine gas exerts a pressure of 900 torr. When the pressure is changed to 1.50 atm, its volume is 250 mL. What was the original volume?

ACTIVITY #10 – GUY-LUSSAC'S LAW PROBLEM SET

Guy-Lussac's Law states that the pressure of a gas varies directly with its Kelvin temperature if volume is held constant. (If one goes up, the other goes up, and vica versa.) We use the formula:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Solve the following problems (assuming constant volume). Assume all number are 3 significant figures.

1. We store and use gases under pressure every day.

    a. List three familiar examples of gases stored under pressure in your home.

    b. List the common safety precaution all three of your examples have in common.

    c. Use Guy-Lussac's law to explain the reason for this precaution.

2. Neon gas is used in glass tubes to make "neon" lights. The glass must be able to withstand great variations of temperature. One night, the temperature is 6.50°C and the neon gas has a pressure of 130 kPa. The sign is turned on and the neon heats up to 670.0°C. What is the new pressure of the neon gas at this temperature?

3. The air inside a tire exerts a pressure of 340 kPa at a temperature of 15°C. What will be the new pressure if the air is cooled to a temperature of -15°C?

4. A compressed gas tank contains air at 95 kPa at a temperature of 22^{o}C. The tank can sustain a maximum pressure of 350 kPa. What is the maximum temperature that the tank can withstand?

5. Your tires are adjusted to 227.5 kPa at 10^{o}C in your mechanic's garage. You then take your car home and park it outside. The overnight temperature drops to -5^{o}C.

    a. Would you expect the tire pressure to increase or decrease?

    b. Determine the new tire pressure.

6. Sometimes, biological samples are stored at low temperatures in nitrogen gas. A sample in a sealed vessel contains a small volume of nitrogen gas at standard pressure (101.3 kPa) at 20^{o}C. The sample is stored at -15^{o}C. What is the final pressure of the nitrogen gas?

ACTIVITY #11 – CHARLES' LAW PROBLEM SET

Charles' Law states the volume of a gas varies directly with the Kelvin temperature, assuming the pressure is constant. We use the following formulas:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{or} \quad V_1 \times T_2 = V_2 \times T_1$$

$$K = °C + 273$$

Solve the following problems assuming a constant pressure. Assume all numbers are 3 significant figures.

1. A sample of nitrogen occupies a volume of 250 mL at 25 °C. What volume will it occupy at 95 °C?

2. Oxygen gas is at a temperature of 40 °C when it occupies a volume of 2.30 Liters. To what temperature should it be raised to occupy a volume of 6.50 Liters?

3. Hydrogen gas was cooled from 150 °C to 50 °C. Its new volume is 75.0 mL. What was its original volume?

4. Chlorine gas occupies a volume of 25.0 mL at 300 K. What volume will it occupy at 600 K?

5. A sample of neon gas at 50 °C and a volume of 2.50 Liters is cooled to 25 °C. What is the new volume?

6. Fluorine gas at 300 K occupies a volume of 500 mL. To what temperature should it be lowered to bring the volume to 300 mL?

7. Helium occupies a volume of 3.80 Liters at –45 °C. What volume will it occupy at 45 °C?

8. A sample of argon gas is cooled and its volume went from 380 mL to 250 mL. If its final temperature was –55 °C, what was its original temperature?

ACTIVITY #12 – CAN'T WE ALL JUST GET ALONG?

In practical terms, it is often difficult to hold any of the variables constant. When there is a change in pressure, volume and temperature, the combined gas law is used. If a variable does not change from initial to final, it can be excluded from the equation.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \text{or} \quad P_1V_1T_2 = P_2V_2T_1$$

Complete the following chart. Show all work on the next page.

	P_1	V_1	T_1	P_2	V_2	T_2
1	1.50 atm	3.00 L	20.0 °C	2.50 atm		30.0 °C
2	720.0 torr	256.0 mL	25.0 °C		250.0 mL	50.0 °C
3	600.0 mmHg	2.50 L	22.0 °C	760.0 mmHg	1.80 L	
4		750.0 mL	0.00 °C	2.00 atm	500.0 mL	25.0 °C
5	95.0 kPa	4.00 L		101.0 kPa	6.00 L	198.0 °C
	650.0 torr		100. °C	900.0 torr	225. mL	150.0 °C
7	850.0 mmHg	1.50 L	15.0 °C		2.50 L	30.0 °C
8	125.0 kPa	125.0mL		100.0 kPa	100 mL	75.0 °C

ACTIVITY #12 – WORK

ACTIVITY #13 – COLD STUFF IS "COOL"

In class, you observed some of the effects that extreme temperature change has on a gas. Two of the examples demonstrated a gas law referred to as Charles' Law. This law describes the relationship between volume of a gas and gas temperature.

In the space below each demonstration, list the observations you made during the demonstration and write a paragraph explaining your observations in terms of Kinetic Molecular Theory.

Demonstration #1 – Balloon vs. Liquid Nitrogen

Observations:

Explanation:

Demonstration #2 – The Bucket Launch

Observations:

Explanation:

ACTIVITY #14 – ONE LAW TO RULE THEM ALL…PIVNERT!

PV = nRT

P = pressure in kPa
V = volume in liters
n = number of moles of gas
R = Universal Gas Constant = 8.314 L·kPa/mol·K
T = Kelvin temperature

1. How many moles of oxygen will occupy a volume of 2.50 liters at 1.20 atm and 25 °C?

2. What volume will 2.00 moles of nitrogen occupy at 720. Mm Hg and 20.°C?

3. What pressure will be exerted by 25.0 g of CO_2 at temperature of 25 °C and a volume of 500. mL?

4. At what temperature will 5.00 g of Cl_2 exert a pressure of 900. mm Hg at a volume of 750. mL?

5. How many moles of nitrogen gas will occupy a volume of 347 mL at 6680 mm Hg and 27 °C?

6. What volume will 454 grams (1 lb) of hydrogen occupy at 1.05 atm and 25 °C?

7. Find the number of grams of CO_2 that exert a pressure of 785 mm Hg at a volume of 32.5 L and a temperature of 32 °C.

8. An elemental gas has a mass of 10.3 g. If the volume is 58.4 L and the pressure is 758 mm Hg at a temperature of 2.5 °C, what is the molar mass of the gas and what is its identity?

ACTIVITY #15 – YOU'RE KIDDING…MORE STOICHIOMETRY?!?!

Consider the following chemical equation:

$$C_2H_5OH\ (l) \ + \ 3\ O_2\ (g) \ \rightarrow \ 2\ CO_2\ (g) \ + \ 3\ H_2O\ (g)$$

1. What type of chemical reaction is this? *Hint: the correct word starts with a "c". . .*

2. Suppose you burn **25 grams** of ethanol (C_2H_5OH) according to the chemical equation shown above. The steps below will lead you through a method to determine how many LITERS of oxygen would be needed to burn all this ethanol.

   a. Use MOLAR MASS to convert **25 GRAMS** of ethanol to **MOLES** of ethanol. Show either dimensional analysis or a proportion as your method for solving this problem.

   b. Now use a **MOLE RATIO** (the coefficients in the balanced chemical equation!) to determine how many MOLES OF OXYGEN GAS would be needed to burn the moles of ethanol you calculated in (i).

   c. To convert MOLES of oxygen gas to LITERS of oxygen gas, you will use the **IDEAL GAS LAW** (pivnert). Assume that the pressure of the oxygen is **normal air pressure** and the temperature is **normal room temperature**.

   d. If you tried to burn **25-grams** of ethanol in a steel box that contains only **5-liters** of oxygen gas (at normal pressure and room temperature), **incomplete combustion** would occur, producing black carbon similar to what we observed when combusting acetylene in Unit 2. Explain why this would happen.

Your Turn:

3. Use the example above to guide your work. Calculate how many **LITERS** of **CARBON DIOXIDE** gas (measured at **27°C** and **0.89 atm**) would be produced from the combustion of **100-GRAMS** of ethanol. *Note: the chemical equation is at the top of the last page!*

Try Some More:

4. When sodium chloride is heated to 800°C it can be electrolytically decomposed into Na metal & chlorine (Cl_2) gas. What volume of chlorine gas is produced (at 800°C and 100 kPa) if 105 g of Na is also produced? [ANS: 204 L]

5. What mass of propane (C_3H_8) can be burned using 100 L of air at 25ºC and 100 kPa? (Hint: air is 20% O_2, so 100 L of air holds 20 L O_2) [ANS: 7 g]

6. A 5.0 L tank holds enough propane (C_3H_8) to exert 13 atm of pressure at 10°C. What volume of O_2 at 10°C & 103 kPa will be required to react with all the propane? [ANS: 320 L]

7. Nitroglycerin explodes according to:

$$4\ C_3H_5(NO_3)_3(l) \rightarrow 12\ CO_2(g) + 6\ N_2(g) + 10\ H_2O(g) + O_2(g)$$

Calculate the volume, at STP, of each product formed by the reaction of 100.0 g of $C_3H_5(NO_3)_3$. [ANS: 29.6 L CO_2, 14.8 L N_2, 29.7 L H_2O, 2.47 L O_2]

ACTIVITY #16 – MMMMM…GIANT MUFFINS…

Baking soda (sodium bicarbonate, $NaHCO_3$) is a commonly used leavening agent in household recipes. When heated to about 100°C, the **sodium bicarbonate** decomposes to form **sodium carbonate**, **water**, and **carbon dioxide**. The CO_2 (g) formed in the reaction will cause a baker's dough to "rise", creating light and fluffy muffins.

Suppose you are trying to make a giant muffin (your choice of flavor). The initial batter has a volume of 400 liters, and you want the baked muffin to occupy a final volume of 1000 liters. You have decided to use baking soda as the sole leavening agent. The muffin will be baked at 350°F (175°C)

What quantity of baking soda in teaspoons would be needed to produce enough CO_2 to raise the muffin batter up to a volume of 1000 liters? Note that one teaspoon of baking soda is approximately 5 grams.

Hint: ***START WITH A BALANCED CHEMICAL EQUATION!*** *Then consider the picture shown below that describes the muffin batter before and after baking. It is CO_2 (g) that "inflates" the muffin.*

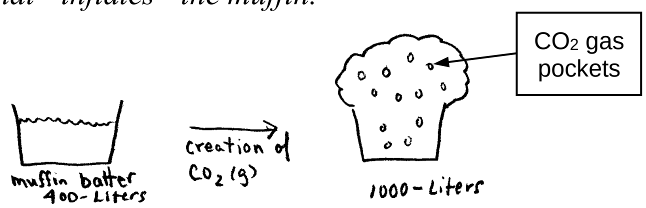
P = _____ (muffin baked at normal pressure)

V = _____ (look at the picture!)

n = _____ (moles of CO_2)

R = _____

T = _____ (must use Kelvin!)



400 Liters batter + ? Liters CO_2 = 1000 Liters total

ACTIVITY #17 – MOLAR VOLUME PRE-LAB DEMO

1. A sample of butane gas from a lighter is collected by water displacement through 21°C H_2O. After equalizing water levels, the volume was 15.0 mL.

   a. Find the volume of dry gas at these conditions.

      Step 1: Determine vapour pressure of water. (chart)

      Step 2: Calculate the pressure of dry butane.

   b. Find the volume of dry gas at STP

      Step 3: Convert to STP using combined gas law.

Your Turn:

2. 37.8 mL of O_2 is collected by the downward displacement of water at 24°C and an atmospheric pressure of 102.4 kPa. What is the volume of dry oxygen measured at STP?

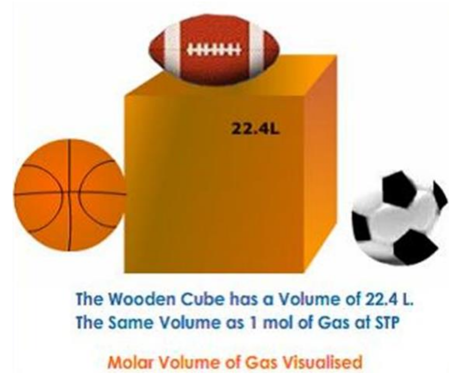
3. How many moles of oxygen were collected? (Hint…Pivnert is the only gas law with moles in it!)

Vapor Pressure of Water

Temperature (°C)	Pressure (kPa)	Temperature (°C)	Pressure (kPa)	Temperature (°C)	Pressure (kPa)
0	0.6	21	2.5	30	4.2
5	0.9	22	2.6	35	5.6
8	1.1	23	2.8	40	7.4
10	1.2	24	3.0	50	12.3
12	1.4	25	3.2	60	19.9
14	1.6	26	3.4	70	31.2
16	1.8	27	3.6	80	47.3
18	2.1	28	3.8	90	70.1
20	2.3	29	4.0	100	101.3

ACTIVITY #18 – DOES A MOLE OF GAS REALLY TAKE UP 22.4 L @ STP?

Purpose: The purpose of this lab is to experimentally determine the molar volume of a gas at STP.



Apparatus:

ring stand	ring	400-mL beaker
eudiometer tube	3M HCl	4-5 cm of Mg ribbon
15 cm of copper wire	graduated cylinder	ruler
centigram balance	distilled water	tap water

Procedure:

1. As a class, determine the mass of 1 meter of Mg ribbon. Put on goggles.
2. Obtain a piece of ribbon between 4.5 and 5.0 cm long. Record its length (±.01 cm).
3. Fold Mg ribbon in half and wrap with copper wire as shown in class. Leave a 15 cm wire "handle."
4. Place about 15 mL of 3M HCl in eudiometer tube. Gently fill the tube to the top with water.
5. Insert Mg ribbon/copper wire into tube so metal will be below the numbers when inverted. Insert stopper to hold the wire in place.
6. Fill 400-mL beaker about 2/3 full of tap water.
7. Place finger over stopper and invert eudiometer tube in the beaker. Observe.
8. When reaction has stopped, tap tube to release any bubbles clinging to the side of the tube. Without losing any liquid, transfer eudiometer tube to the graduated cylinder and equalize inside and outside pressure. Record volume of gas inside the tube.
9. Obtain matches and wood splint. Test gas to verify that it acts like hydrogen. Keep wood splint for others.
10. Clean apparatus and station.

Data:

mass of 1 meter Mg = _______________ g

length of Mg ribbon = _______________ cm (read to 2 decimal places)

room pressure = _______________ mmHg

room temperature = _______________ °C

volume of H_2 = _______________ mL *(read this in the grad. cylinder with liquid levels equalized)*

equilibrium vapor pressure of water at today's temperature = _______________ mmHg (from "CRC")

Questions and Calculations:

1. Write a balanced chemical equation for the reaction between Mg ribbon and hydrochloric acid.

2. Calculate the number moles of $H_2(g)$ formed beginning with the length of magnesium ribbon used.

3. Show your calculation of the partial pressure of hydrogen gas inside the tube. This is the pressure you should use for the room pressure of the hydrogen gas. [Note that another definition of partial pressure is the pressure the hydrogen gas would exert if it were alone in the tube. This is also called the pressure of dry hydrogen.]

4. Calculate the volume of your dry H_2 gas if it were measured at STP. Show the calculation.

   Variables:

Room Conditions	**STP**
volume of H_2 (data) =	volume of H_2 at STP = x =
room temperature (data) =	temperature at STP = 273 K
pressure of gas (#3) =	pressure at STP = 760 mmHg

5. Calculate the volume of hydrogen (at STP) you would have obtained if you had reacted 1.00 mole Mg ribbon (the "molar volume") at STP. Report your answer in Liters.

6. Knowing that the molar volume of a gas at STP ***should be*** 22.4 L, calculate the % error for **your** value.

8. If some of the gas bubbles from the reaction had escaped out the bottom of the tube, how would this have affected your molar volume at STP? Explain.

9. If some of the Mg ribbon had not reacted because it stuck to the side of the tube and did not contact the acid, how would this have affected your molar volume at STP? Explain.

ACTIVITY #19 – UNIT TEST REVIEW

TOPIC 1: PRESSURE CONVERSIONS

1 atm = 760 mmHg = 760 torr = 14.7 psi = 101.3 kPa

Perform the following conversions: (Show your work)

550 mmHg x ____________ = kPa

55 psi x ____________ = mmHg

325 kPa x ____________ = atm

2284 torr x ____________ = kPa

48.0 mmHg x ____________ = torr

1.85 atm x ____________ = mmHg

TOPIC 2: KELVIN TEMPERATURE

K = °C + 273

Convert:

26.0 °C = _______ K

400 K = ______ °C

100 K = _______ °C

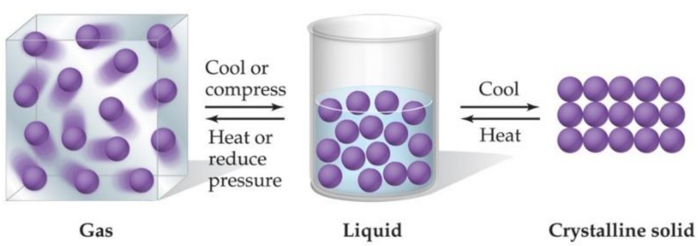
135 °C = ________ K

-127 °C = _______ K

4 K = _______°C

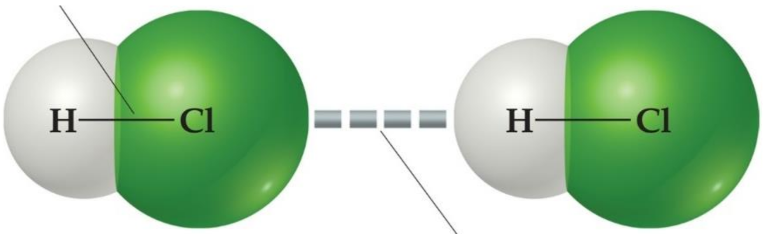
What is the temperature of a sample of gas that has **double** the kinetic energy (motion energy) of a sample of gas at 80°C?

TOPIC 3: STATES OF MATTER



Which molecules above:

have the highest kinetic energy?		display mostly translational motion?	
have the lowest boiling point?		have the strongest intermolecular attractions?	
can fill their container?		have a constant volume?	
create pressure?		have a constant mass?	
display only vibrational motion?		have the weakest intermolecular forces?	



Label the **intra**molecular bond(s) in the diagram above.

Label the **inter**molecular bond(s) in the diagram above.

Which attractions contribute to the state of matter of the substance? Explain how the attractions you chose dictate the state of matter?

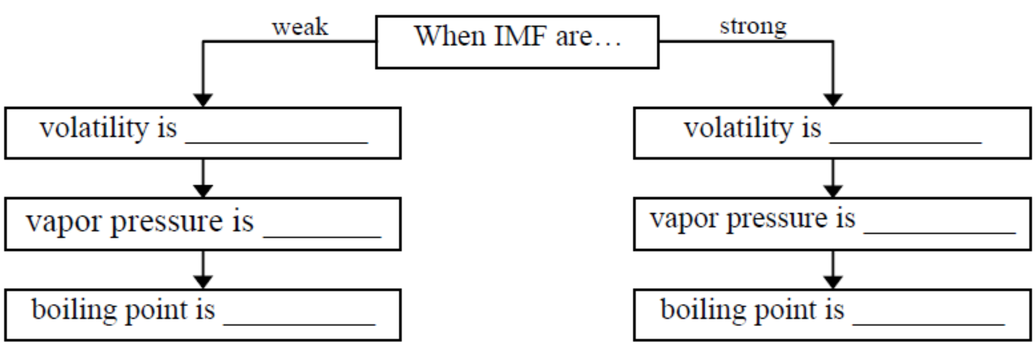
Explain the relationship between temperature, intermolecular attractions, and state of matter.

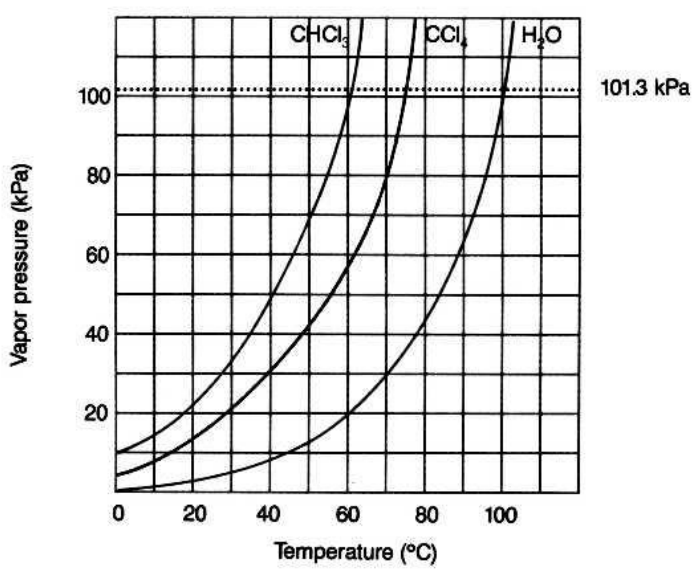
TOPIC 5: VAPOUR PRESSURE

Explain what vapor pressure is and how it occurs.

Define the boiling point of a liquid in terms of vapor pressure and temperature.

Fill in the diagram below with either the word "high" or "low" to show how intermolecular forces (IMF's) influence the volatility, vapor pressure, and boiling point of a substance.





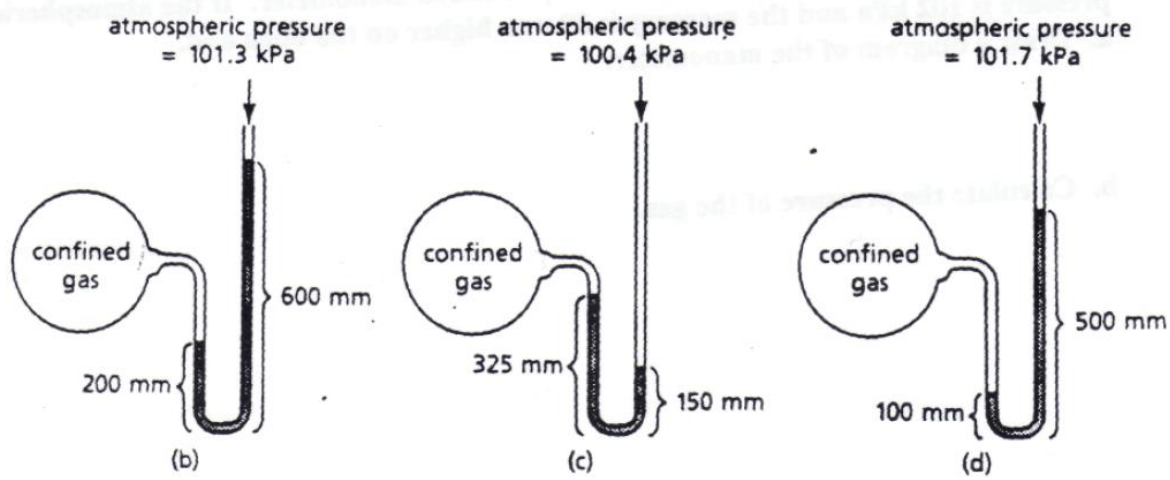
What is the vapor pressure of CCl_4 at 40°C?

What is the boiling point of H_2O when the external pressure is 60 kPa?

What is the normal boiling point of $CHCl_3$?

Which substance has the strongest intermolecular attractions? Why do you say this?

TOPIC 7: MANOMETERS



Which of the manometers above show a confined gas with a greater vapor pressure than the atmosphere?

Calculate the vapor pressure of each of the confined gases above.

TOPIC 8: GAS VARIABLE RELATIONSHIPS

Circle the correct term to describe the variables (DP = directly proportional, IP = inversely proportional)

Volume and Pressure	*Volume and Temperature*	*Volume and Moles*	*Pressure and Temp*
DP IP	DP IP	DP IP	DP IP

TOPIC 9: IDENTIFYING PROBLEMS

Identify the variables in each problem and decide which law applies. **You do not have to solve the problems.**

____________ A balloon at 35°C has a volume of 2.5 L. What is its volume at 45°C?

____________ A balloon has a volume of 3.50 L at 21.0°C when the air pressure is 1.05 atm. How many moles of gas are contained in the balloon?

____________ A balloon has a volume of 1.0 L at 750 mmHg. What is the balloon's volume at 101.3 kPa?

TOPIC 10: GAS LAWS

Solve the following problems:

____________ A balloon at 35°C has a volume of 2.5 L. What is its volume at 45°C?

____________ A balloon has a volume of 3.50 L at 21.0°C when the air pressure is 1.05 atm. How many moles of gas are contained in the balloon?

____________ A balloon has a volume of 1.0 L at 750 mmHg. What is the balloon's volume at 121.3 kPa?

TOPIC 11: KINETIC MOLECULAR THEORY

Explain the following observations in terms of the "kinetic molecular theory" (that is, what do the gas particles look like?)

A balloon of gas is placed in a car on a hot day. The balloon gets larger. **WHY?**

A syringe is squeezed so the gas sample changes from 10 ml to 5 ml. The pressure doubles. **WHY?**

A pot of water on top of Mt. Everest starts to boil at 60ºC? **WHY?**

TOPIC 12: IDEAL GAS LAW

Solve the following problems using the Ideal Gas Law: (Identify the variables and show work)

A 10.0 gram chunk of dry ice (solid CO_2) changes to gas. What is the volume of that gas measured at 27°C and 740 mmHg?

P =

V =

n =

R =

T =

TOPIC 13: MOLAR MASS OF A GAS

PV = nRT can be used to find the molar mass of gases as well!

Calculate the molar mass of a gas sample if 3.0 grams of the gas in a 2.0 L container at 25°C has a pressure of 2.294 atm. Assuming the sample is an elemental gas, what is the probable identity of the gas?

TOPIC 14: MORE STOICH!

Ethylene burns in oxygen to form carbon dioxide and water vapor:

$$C_2H_{4(g)} + 3\ O_{2(g)} \rightarrow 2\ CO_{2(g)} + 2\ H_2O_{(g)}$$

How many grams of water can be formed if 1.25 liters of ethylene are consumed in this reaction if it takes place at 1.2 atm and 25°C?

TOPIC 15: LAB WORK

Information:
volume of gas at room conditions: 45.0 mL
length of Mg used: 4.65 cm
mass of 1.00 m of Mg: 0.958 g

How many moles of magnesium were used? Show work.

What is the molar volume of this hydrogen gas sample **under room conditions**? Show work.

TOPIC 16: MORE LAB WORK

Information:
molar volume of gas at room conditions: 25.6 L/mol
room temperature: 21.0 °C
pressure of dry hydrogen gas: 735 mmHg.

What is the molar volume of this hydrogen gas sample at STP? Identify the variables and show work.

P_1=		P_2=	
V_1=		V_2=	
T_1=		T_2=	

GAS LAW CHEAT SHEET

$$P_1V_1 = P_2V_2$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$PV = nRT$$

$$P_t = P_1 + P_2 + P_3 \ldots$$

1 atm = 101.325 kPa = 760 mm Hg = 760 Torr = 14.7 psi

0 Kelvin = -273^{o}C

STP (Standard Temperature & Pressure) = 101.3 kPa & <u>0^{o}C</u>

SATP (Standard Ambient Temperature & Pressure) = 101.3 kPa & <u>25^{o}C</u>

P = pressure
V = volume
n = moles
R = Ideal Gas Constant (8.314 kPa·L·mol^{-1}·K^{-1})
T = Temperature (K)

SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > 0.1 mol/L at 25°C.

Negative Ions (Anions)	Positive Ions (Cations)	Solubility of Compounds
All	Alkali ions: Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	Soluble
All	Hydrogen ion: H^+	Soluble
All	Ammonium ion: NH_4^+	Soluble
Nitrate, NO_3^-	All	Soluble
Chloride, Cl^- or Bromide, Br^- or Iodide, I^-	All others	Soluble
	Ag^+, Pb^{2+}, Cu^+	Low Solubility
Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Low Solubility
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Sr^{2+}	Soluble
	All others	Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Low Solubility

PERIODIC TABLE OF IONS

TABLE OF POLYATOMIC IONS

acetate	CH_3COO^-	dihydrogen phosphate	$H_2PO_4^-$	oxalate	$C_2O_4^{2-}$
arsenate	AsO_4^{3-}	hydrogen carbonate	HCO_3^-	perchlorate	ClO_4^-
arsenite	AsO_3^{3-}	hydrogen oxalate	$HC_2O_4^-$	periodate	IO_4^-
benzoate	$C_6H_5COO^-$	hydrogen sulfate	HSO_4^-	permanganate	MnO_4^-
borate	BO_3^{3-}	hydrogen sulfide	HS^-	peroxide	O_2^{2-}
bromate	BrO_3^-	hydrogen sulfite	HSO_3^-	phosphate	PO_4^{3-}
carbonate	CO_3^{2-}	hydroxide	OH^-	pyrophosphate	$P_2O_7^{4-}$
chlorate	ClO_3^-	hypochlorite	ClO^-	sulfate	SO_4^{2-}
chlorite	ClO_2^-	iodate	IO_3^-	sulfite	SO_3^{2-}
chromate	CrO_4^{2-}	monohydrogen phosphate	HPO_4^{2-}	thiocyanate	SCN^-
cyanate	CNO^-	nitrate	NO_3^-	thiosulfate	$S_2O_3^{2-}$
cyanide	CN^-	nitrite	NO_2^-	**POSITIVE POLYATOMIC IONS**	
dichromate	$Cr_2O_7^{2-}$	orthosilicate	SiO_4^{4-}	ammonium	NH_4^+
				hydronium	H_3O^+

KEY

atomic number → 26; symbol → Fe^{3+} (ion charge); ion name (IUPAC) → iron (III); Fe^{2+} iron (II)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H^+ hydrogen																1 H^- hydride	2 He helium
3 Li^+ lithium	4 Be^{2+} beryllium											5 B boron	6 C carbon	7 N^{3-} nitride	8 O^{2-} oxide	9 F^- fluoride	10 Ne neon
11 Na^+ sodium	12 Mg^{2+} magnesium											13 Al^{3+} aluminum	14 Si silicon	15 P^{3-} phosphide	16 S^{2-} sulfide	17 Cl^- chloride	18 Ar argon
19 K^+ potassium	20 Ca^{2+} calcium	21 Sc^{3+} scandium	22 Ti^{4+} titanium (IV) / Ti^{3+} titanium (III)	23 V^{3+} vanadium(III) / V^{5+} vanadium (V)	24 Cr^{3+} chromium (III) / Cr^{2+} chromium (II)	25 Mn^{2+} manganese(II) / Mn^{4+} manganese(IV)	26 Fe^{3+} iron (III) / Fe^{2+} iron (II)	27 Co^{2+} cobalt (II) / Co^{3+} cobalt (III)	28 Ni^{2+} nickel (II) / Ni^{3+} nickel (III)	29 Cu^{2+} copper (II) / Cu^+ copper (I)	30 Zn^{2+} zinc	31 Ga^{3+} gallium	32 Ge^{4+} germanium	33 As^{3-} arsenide	34 Se^{2-} selenide	35 Br^- bromide	36 Kr krypton
37 Rb^+ rubidium	38 Sr^{2+} strontium	39 Y^{3+} yttrium	40 Zr^{4+} zirconium	41 Nb^{5+} niobium (V) / Nb^{3+} niobium(III)	42 Mo^{6+} molybdenum	43 Tc^{7+} technitium	44 Ru^{3+} ruthenium(III) / Ru^{4+} ruthenium(IV)	45 Rh^{3+} rhodium	46 Pd^{2+} paladium(II) / Pd^{4+} paladium(IV)	47 Ag^+ silver	48 Cd^{2+} cadmium	49 In^{3+} indium	50 Sn^{4+} tin (IV) / Sn^{2+} tin (II)	51 Sb^{3+} antimony(III) / Sb^{5+} antimony(V)	52 Te^{2-} telluride	53 I^- iodide	54 Xe xenon
55 Cs^+ cesium	56 Ba^{2+} barium	57 La^{3+} lanthanum	72 Hf^{4+} hafnium	73 Ta^{5+} tantalum	74 W^{6+} tungsten	75 Re^{7+} rhenium	76 Os^{4+} osmium	77 Ir^{4+} iridium	78 Pt^{4+} platinum(IV) / Pt^{2+} platinum(II)	79 Au^{3+} gold (III) / Au^+ gold (I)	80 Hg^{2+} mercury (II) / Hg_2^{2+} mercury (I)	81 Tl^+ thallium (I) / Tl^{3+} thallium(III)	82 Pb^{2+} lead (II) / Pb^{4+} lead (IV)	83 Bi^{3+} bismuth(III) / Bi^{5+} bismuth(V)	84 Po^{2+} polonium(II) / Po^{4+} polonium(IV)	85 At^- astatide	86 Rn radon
87 Fr^+ francium	88 Ra^{2+} radium	89 Ac^{3+} actinium															

58 Ce^{3+} cerium	59 Pr^{3+} praseodymium	60 Nd^{3+} neodymium	61 Pm^{3+} promethium	62 Sm^{3+} samarium(III) / Sm^{2+} samarium(II)	63 Eu^{3+} europium (III) / Eu^{2+} europium (II)	64 Gd^{3+} gadolinium	65 Tb^{3+} terbium	66 Dy^{3+} dysprosium	67 Ho^{3+} holmium	68 Er^{3+} erbium	69 Tm^{3+} thulium	70 Yb^{3+} ytterbium(III) / Yb^{2+} ytterbium(II)	71 Lu^{3+} lutetium
90 Th^{4+} thorium	91 Pa^{5+} protactinium(V) / Pa^{4+} protactinium(IV)	92 U^{6+} uranium (VI) / U^{4+} uranium (IV)	93 Np^{5+} neptunium	94 Pu^{4+} plutonium(IV) / Pu^{6+} plutonium(VI)	95 Am^{3+} americium(III) / Am^{4+} americium(IV)	96 Cm^{3+} curium	97 Bk^{3+} berkelium(III) / Bk^{4+} berkelium(IV)	98 Cf^{3+} californium	99 Es^{3+} einsteinium	100 Fm^{3+} fermium	101 Md^{2+} mendelevium (II) / Md^{3+} mendelevium (III)	102 No^{2+} nobelium(II) / No^{3+} nobelium(III)	103 Lr^{3+} lawrencium

The Periodic Table of the Elements

Average relative masses are rounded to two decimal places.

Element name → Mercury
Atomic # → 80
Symbol → Hg
Avg. Mass → 200.59

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hydrogen 1 **H** 1.01																		Helium 2 **He** 4.00
Lithium 3 **Li** 6.94	Beryllium 4 **Be** 9.01												Boron 5 **B** 10.81	Carbon 6 **C** 12.01	Nitrogen 7 **N** 14.01	Oxygen 8 **O** 16.00	Fluorine 9 **F** 19.00	Neon 10 **Ne** 20.18
Sodium 11 **Na** 22.99	Magnesium 12 **Mg** 24.31												Aluminum 13 **Al** 26.98	Silicon 14 **Si** 28.09	Phosphorus 15 **P** 30.97	Sulfur 16 **S** 32.07	Chlorine 17 **Cl** 35.45	Argon 18 **Ar** 39.95
Potassium 19 **K** 39.10	Calcium 20 **Ca** 40.08		Scandium 21 **Sc** 44.96	Titanium 22 **Ti** 47.88	Vanadium 23 **V** 50.94	Chromium 24 **Cr** 52.00	Manganese 25 **Mn** 54.94	Iron 26 **Fe** 55.85	Cobalt 27 **Co** 58.93	Nickel 28 **Ni** 58.69	Copper 29 **Cu** 63.55	Zinc 30 **Zn** 65.39	Gallium 31 **Ga** 69.72	Germanium 32 **Ge** 72.61	Arsenic 33 **As** 74.92	Selenium 34 **Se** 78.96	Bromine 35 **Br** 79.90	Krypton 36 **Kr** 83.80
Rubidium 37 **Rb** 85.47	Strontium 38 **Sr** 87.62		Yttrium 39 **Y** 88.91	Zirconium 40 **Zr** 91.22	Niobium 41 **Nb** 92.91	Molybdenum 42 **Mo** 95.94	Technetium 43 **Tc** (97.91)	Ruthenium 44 **Ru** 101.07	Rhodium 45 **Rh** 102.91	Palladium 46 **Pd** 106.42	Silver 47 **Ag** 107.87	Cadmium 48 **Cd** 112.41	Indium 49 **In** 114.82	Tin 50 **Sn** 118.71	Antimony 51 **Sb** 121.76	Tellurium 52 **Te** 127.60	Iodine 53 **I** 126.90	Xenon 54 **Xe** 131.29
Cesium 55 **Cs** 132.91	Barium 56 **Ba** 137.33	57-70 *	Lutetium 71 **Lu** 174.97	Hafnium 72 **Hf** 178.49	Tantalum 73 **Ta** 180.95	Tungsten 74 **W** 183.84	Rhenium 75 **Re** 186.21	Osmium 76 **Os** 190.23	Iridium 77 **Ir** 192.22	Platinum 78 **Pt** 195.08	Gold 79 **Au** 196.97	Mercury 80 **Hg** 200.59	Thallium 81 **Tl** 204.38	Lead 82 **Pb** 207.20	Bismuth 83 **Bi** 208.98	Polonium 84 **Po** (208.98)	Astatine 85 **At** (209.99)	Radon 86 **Rn** (222.02)
Francium 87 **Fr** (223.02)	Radium 88 **Ra** (226.03)	89-102 **	Lawrencium 103 **Lr** (262.11)	Rutherfordium 104 **Rf** (265.12)	Dubnium 105 **Db** (268.13)	Seaborgium 106 **Sg** (271.13)	Bohrium 107 **Bh** (270)	Hassium 108 **Hs** (277.15)	Meitnerium 109 **Mt** (276.15)	Darmstadtium 110 **Ds** (281.16)	Roegentium 111 **Rg** (280.16)	Copernicium 112 **Cn** (285.17)	Nihonium 113 **Nh** (284.18)	Flerovium 114 **Fl** (289.19)	Moscovium 115 **Mc** (288.19)	Livermorium 116 **Lv** (293)	Tennessine 117 **Ts** (294)	Oganesson 118 **Og** (294)

*lanthanides	Lanthanum 57 **La** 138.91	Cerium 58 **Ce** 140.12	Praseodymium 59 **Pr** 140.91	Neodymium 60 **Nd** 144.24	Promethium 61 **Pm** (145)	Samarium 62 **Sm** 150.36	Europium 63 **Eu** 151.97	Gadolinium 64 **Gd** 157.25	Terbium 65 **Tb** 158.93	Dysprosium 66 **Dy** 162.50	Holmium 67 **Ho** 164.93	Erbium 68 **Er** 167.26	Thulium 69 **Tm** 168.93	Ytterbium 70 **Yb** 173.05
**actinides	Actinium 89 **Ac** (227.03)	Thorium 90 **Th** 232.04	Protactinium 91 **Pa** 231.04	Uranium 92 **U** 238.03	Neptunium 93 **Np** (237.05)	Plutonium 94 **Pu** (244.06)	Americium 95 **Am** (243.06)	Curium 96 **Cm** (247.07)	Berkelium 97 **Bk** (247.07)	Californium 98 **Cf** (251.08)	Einsteinium 99 **Es** (252.08)	Fermium 100 **Fm** (257.10)	Mendelevium 101 **Md** (258.10)	Nobelium 102 **No** (259.10)