name

Gas PACK

How to do well on the Gas Chem Celebration…

Be able to explain all points of the KMT, the Kinetic Molecular Theory (don't memorize it).

Be able to describe the difference between real and ideal gases.

Be able to draw perfect graphs that show the relationships between:
Pressure + Volume, Pressure + Temperature, and Volume + Temperature.
Know which of these relationships are directly proportional, and which is inversely proportional.

Be able to state and explain Avogadro's Hypothesis

Be able to calculate all pressure conversions (atm, kPa, psi, and mm of Hg)

Be able to calculate any type of combined gas law problems.

Read the BASICS. Re-read the BASICS.

☺

Gas BASICS

Gases are the most interesting phase because mostly they are invisible and you have to use your measuring and wits to grasp how perfect they are. You already know that gases follow the Kinetic Molecular Theory, which is covered again just below. Some of the theory is perfectly true but sometimes the theory "fibs" to help you grasp how gases are gases, and how they stay gases.

Nearly all substances can be phase-changed into gases, but for many this happens only at very high temperatures passed their boiling point. H_2O boils into a gas at 373 K at standard pressure. Iron gas forms at 3023 K, and that is remarkably hot! For example, that doesn't, think about wood, or certain plastics. They might catch fire or decompose before they can change into the gas phase.

There's also the idea of "ideal gases" which are the theoretical perfection of gases, but they are not real. They are like super heroes. We know that super heroes are fake - but we accept them because it makes for a good movie, or in this case, makes it easier to understand gases in general.

Ideal gases: are perfect, make believe, super hero gases. They are the idea of gases, but there are no examples of ideal gases, none exist. Real gases are real; they exist on the periodic table and in the air. Ideal gases are used to help explain what gases are. They are the gases of the KMT (below). They are a "model" of gases, not actual gases.

Ideal gases are models, or conceptualizations of gases.
Real gases can turn into liquids, because they are real.
Ideal gases are perfect gases and can't ever become liquid or solid.

Real gases act most ideally when it is at high temperature, and it is at low pressure. This is because at high temperatures, any particle collisions are strong enough that the gas particles bounce off each other rather than stick to form a liquid. At low pressure they collide less frequently and have much less chance of forming into a liquid. The biggest flaw a gas can have is to become a liquid! That means a real gas most closely follows the Kinetic Molecular Theory when it's at high temp & low pressure.

When comparing two real gases that are at the same conditions, the one with the smaller particles is more ideal. Helium is the most ideal of the real gases, because they are the smallest particles.

Carbon dioxide is "more ideal" than octane, when both are at the same temperature and pressure, because the CO_2 particles are smaller than the C_8H_{18} particles.

There are some gases that are atomic— they exist as single atoms, which are the noble gases. Other gases are diatomic, or paired, like the HONClBrIF twins: H_2, O_2, N_2, Cl_2, Br_2, I_2, and F_2 . Bromine is a liquid at room temperature, and iodine is a solid, but both Br_2 and I_2 become gases are relatively low temperatures.

Some gases are compounds, like CO_2, SO_3, methane CH_4, etc.

And there are a few odd gases that we'll learn about like: ozone O_3.

Remember the formula for laughing gas: He, He, He!

The Kinetic Molecular Theory of Gases (from NYS Curriculum)

3.4a The concept of an ideal gas is a model to explain the behavior of gases. A real gas is most like an ideal gas when the real gas is at low pressure & high temperature.

Because at high temperatures, the collisions between particles is so strong that the atoms or molecules are less likely to collect together (as a liquid). At low pressure there are much fewer collisions, much less change to collect together as a liquid as well.

3.4b Kinetic molecular theory (KMT) for an ideal gas states that all gas particles:

- are in random, constant, straight-line motion.
- are separated by great distances relative to their size;
- the volume of the gas particles is considered negligible.
- have no attractive forces between them.
- have collisions that may result in a transfer of energy between gas particles, but the total energy of the system remains constant.

3.4c Kinetic molecular theory describes the relationships of pressure, volume, temperature, velocity, and frequency and force of collisions among gas molecules.

There are no ideal gases in rea life. Ideal gases are like Superman or Superwoman, idealized heroes, to aspire to be like, but we know we can't be perfect. Gases can't be perfect either. There is some overlap between theory and real gases, but sometimes science is needed to explain why gases are obviously not ideal, but they remain gases and don't condense into liquids all of the time.

Measuring Gases

We will measure gases 4 ways in our class, the gas pressure, the gas volume, the gas temperature, and the number of moles of gas.

1. Volume: Volume is measured in liters of space, or milliliters of space (mL) Converting from these units means knowing that 1 Liter = 1000 milliliters

2. Temperature: Gases will be measured in Kelvin only, because when we use our formulas, a temperature of zero (as in 0°C) or a negative number (such as -4.5°C) will collapse the math. Zero Kelvin means absolute zero.

3. Number of Moles: Is just what is says, how many moles of gas are present.

4. Pressure: Pressure is measured in 4 different units that you know. All of these have unlimited SF. Standard pressure is what chemists agree is "normal" pressure. In four units normal or STANDARD PRESSURE is:

101.3 kilo-Pascals (kPa)
1 atmosphere (atm)
760 millimeters of mercury (mm Hg)
14.7 pounds per square inch (psi)

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

The relationship between
Pressure, Volume and Temperature of gases.

Gases three main measures, pressure and volume and temperature are all in different relationships with each other at the same time. Let's explore the three of these now.

The combined gas law, at right, connects all three of these variables. The starting conditions of pressure multiplied by the volume, which is then divided by the Kelvin Temperature is equal to the new conditions of the gas, pressure X volume, then divided by the Kelvin Temperature.

We always use Kelvin because having a negative number, or a zero as a denominator will wreck our math. Units for pressure or volume can be whichever you choose, as long as they are the same on both sides of the equal sign.

Gas math problems have a lot of words; there are six variables and you need to be told five of them. Sometimes the letters STP are used for two variables at once, standard temperature and standard pressure. They are in your reference tables, any units will work, but read the problem, if you start or end at STP, but the pressure units must be consistent on both sides of the = sign. PSI can't just "turn into" kPa or mm Hg.

Example problem one…

Your balloon holds 15.6 liters of helium gas at STP, when it rises into the night air, the temperature drops down to just 255 Kelvin, and the volume shrinks to 12. 3 Liters. What is the new pressure? (note, you are given five of six variables, solve for the last one, make sure you put the numbers and units in the right place, and then it's just a simple cross multiply and divide to solve for the missing variable).

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$	$\frac{(1\text{ atm})(15.6\text{ L})}{273\text{ Kelvin}}$	=	$\frac{(P_2)(12.3\text{ L})}{255\text{ Kelvin}}$
	$(1\text{ atm})(15.6\text{ L})(255\text{ K}) = (P_2)(12.3\text{ L})(273\text{ K})$		
	$\frac{(1\text{ atm})(15.6\text{ L})(255\text{ K})}{(12.3\text{ L})(273\text{ K})}$	=	P_2
	$1.18\text{ atm} = P_2$		

That is as hard as these problems might get, which is not bad. What is important to see is what might happen if the problem says, for example, pressure temperature remains constant. Or one of the other variables remains constant.

You can always choose the same number with unit to use on both sides of the = sign, these will cancel each other out, or you can cancel part of the combined gas law formula out, which is what you will see on the next page. Either way, the same answers come out.

Always use the same units on both sides of the = sign, and always use Kelvin, never centigrade, or worse, the "F" word (Fahrenheit!).

Mathematically we can look at this formula in parts as well. Algebra allows us to have, for example, constant temperature. That changes the math to just $P_1V_1 = P_2V_2$ (temperature cancels out).

The pressure and the volume of a gas are in what is called an INVERSELY PROPORTIONAL relationship. As one variable increases, the other decreases.

A problem might read… A gas held at constant temperature is 35.5 Liters and at 1.45 atm. If pressure increases to 2.78 atm what is the new volume?

Cancelling out the temperature (it's constant), we can use this formula: $P_1V_1 = P_2V_2$

$P_1V_1 = P_2V_2 \rightarrow (1.45\text{ atm})(33.5\text{ L}) = (2.78\text{ atm})(V_2) \qquad V_2 = 17.5\text{ Liters}$

This math provides the same answer even if we used the "whole" combined gas law.
If you inserted ANY TEMP for T_1 and also for T_2 (since temperature is constant).
The answer is always 17.5 Liters.

If Pressure were constant, we could omit P_1 and P_2 from the formula in the same way.
If Volume were constant, we could omit the V_1 and the V_2 from the formula as well.
Or you could use 1 atm as P_1 and P_2, or 22.4 Liters for V_1 and V_2, the math the same works either way.

Separating the parts of the combined gas law into its "component parts", there are three smaller gas laws inside of it. You do not have to know them by name, but they are real gas laws that have been mathematically combined into just one big COMBINED GAS LAW.

$P_1V_1 = P_2V_2$	This is Boyle's Law. (that's a name you do not have to remember) This law shows that Pressure and Volume are INVERSELY PROPORTIONAL The math shows as one variable increases, the other must decrease proportionally.
$\frac{P_1}{T_1} = \frac{P_2}{T_2}$	This is the Gay-Lussac Law. (another name you don't need to remember) This law shows that the pressure and temperature are DIRECTLY PROPORTIONAL. As one variable increases or decreases, the other increases or decreases proportionally.
$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	This is Charles' Law. (the third name that is not necessary to memorize). This law shows that the Volume and Temperature are DIRECTLY PROPORTIONAL. As one variable increases or decreases, the other increases or decreases proportionally.

All gas problems can be solved with the combined gas law formula. But, if one variable is a constant, you can omit it prior to the math, or insert the same value on both sides of the equal sign. Remember, you must use Kelvin temperature only, that prevents you from getting a negative number or a zero as a denominator.

Example problems….

1. At constant pressure, a sample of gas of 22.4 Liters and standard temperature is warmed up to 365 Kelvin. What is the new volume of this gas?
You could decide to use 1 atm pressure on both sides of the equal sign or use the smaller formula that omits the pressure before the math.

V_1	=	V_2	→	22.4 L	=	V_2	→	$(V_2)(273\text{ K}) = (22.4\text{ L})(365\text{ K})$
T_1		T_2		273 K		365 K		$V_2 = 29.9$ Liters

2. At constant volume, a gas sample at standard pressure and 303 Kelvin is cooled to just 245 Kelvin. What is the new pressure on this gas?

P_1	=	P_2	→	101.3 kPa	=	P_2	→	$(P_2)(303\text{ K}) = (101.3\text{ kPa L})(245\text{ K})$
T_1		T_2		303 K		245 K		$P_2 = 81.9$ kPa

All combined gas law problems can be solved with the combined gas law, or one of the three smaller laws, if there are two variables and one constant in the math. You'll get the same answer either way.

Avogadro's Hypothesis

Amedo Avogadro has that famous number named after him (6.02 x 10^{23} particles in one mole). He studied gases and came up with one of the best "one liners" in chemistry history, which is Avogadro's Hypothesis. It would be a law, but no one can count that high. Memorize this…

"EQUAL VOLUMES OF DIFFERENT GASES AT THE SAME TEMPERATURE & PRESSURE HAVE THE SAME NUMBER OF PARTICLES, AND THE SAME NUMBER OF MOLES."

Go slowly through the diagram and figure this out.
In each of these containers is 22.4 Liters in volume. Each is at STP. Each has a different gas inside

Remember that 22.4 Liters of any gas at STP is ONE MOLE of gas.
Therefore, each container has ONE MOLE, or 6.02 x 10^{23} particles, but of different gases.

Equal volumes	volume in Liters	22.4 liters of	22.4 liters of	22.4 liters of
of Different gases	Type of gas	argon	oxygen	nitrogen
at same temp and pressure	Pressure in kPa	101.3	101.3	101.3
	Temp in Kelvin	273 K	273 K	273 K
have same number of moles, and particles.	# of moles	1.0 mole	1.0 mole	1.0 mole
	# of particles	6.02 x 10^{23}	6.02 x 10^{23}	6.02 x 10^{23}

Memorizing this will save you from doing tedious math problems. You can memorize it or grunt out all of the math to figure out regents questions like this.

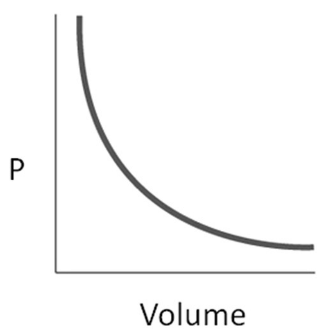
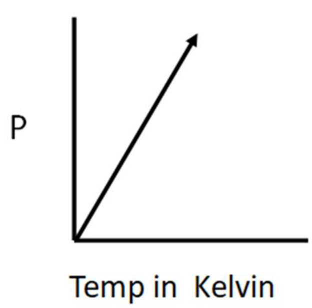
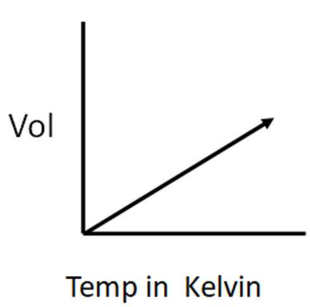
Which sample has the same number of molecules as 3.69 Liters of carbon dioxide at 125 kPa and 305 Kelvin?

A. 1.23 Liters of N_2 at125 kPa and 305 Kelvin
B. 3.69 Liters of CH_4 at 125 kPa and 305 Kelvin
C. 7. 38 Liters of CO at125 kPa and 305 Kelvin
D. 1.00 liters of C_8H_{18} at125 kPa and 305 Kelvin

The answer is B.
Equal volumes of different gases at the same temp & pressure have the same number of particles (or moles). The type of gas does not matter, Avogadro does.

The Graphs showing the relationships of Pressure—Volume—Temperature of Gases.

You will have to recognize and draw graphs showing the inversely proportional relationship of P and V. You will also have to recognize and draw graphs showing the directly proportional relationships between P and T, and between V and T.

	Pressure as a function of Volume As one variable increases, the other decreases. or As one variable decreases, the other increases.
	Pressure as a function of Temperature As one variable increases, the other also increases. or As one variable decreases, the other does too. Temperature MUST be in KELVIN.
	Volume as a function of Temperature As one variable increases, the other increases. or As one variable decreases, the other does too. Temperature MUST be in KELVIN.

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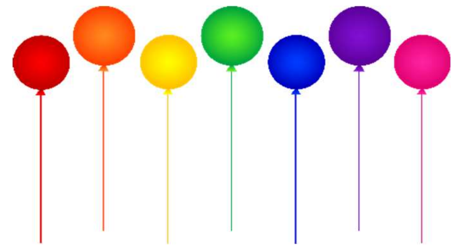
Gas Notes

1. Write the combined gas law



2. Which we say like this:

____

3. And THAT MEANS: that if you know the ORIGINAL CONDITIONS of _____________,

_______________, and __________________________, you can…

4. The pressure units we could use are:____

5. The volume units we could use are:____

6. Units for temperature are always _________________________ (no matter what)

7. Your balloon is filled on the ground. It's 45.6 liters in size, the helium is at a pressure of 1.20 atm, at 293 K. The balloon rises and the temperature drops to 278 K; the pressure drops to 1.05 atm. What's the new volume of the balloon?

8. A weather balloon has been filled with helium to a volume of 65.5 liters, at 1.50 atm, temperature is 295 K. The balloon cools to 265 K, and the volume changes to 72.0 Liters. What is the pressure in this balloon under these new conditions?

9. At constant temperature, a sample of CO_2 is at 50.0 cm^3 and 125 kPa is put into a much larger container and it expands to 385 cm^3. What's the new pressure of the gas?

10. At constant pressure, 12.0 liters of CH_4 gas at 24.0°C is cooled down to -15.0°C. What does the gas volume change to?

11. At a constant volume of 450.0 mL, a sample of oxygen gas is at 165 kPa, and standard temperature. If it is heated up to 349 K, what is the new pressure on this gas?

<table>
<tr><th>FILL IN
Review Guide</th><th>formula</th><th>Show a simple graph of this relationship</th><th>Name this relationship

inversely or directly
proportional. Or both.</th></tr>
<tr><td>The
Combined gas law</td><td></td><td>X</td><td></td></tr>
<tr><td>Combined gas law
with
constant temp</td><td></td><td></td><td></td></tr>
<tr><td>Combined gas law
with
constant pressure</td><td></td><td></td><td></td></tr>
<tr><td>Combined gas law
with
constant volume</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">The combined gas law is the starting point for every single gas problem in our course. Sometimes one of the three variables is a constant, and we can cancel it out before the math.
• The temperature MUST ALWAYS BE KELVIN. WHY?</td></tr>
</table>

14. With CONSTANT TEMPERATURE we can change this formula to… (Boyle's Law)	
15. DRAW Charlie's CO_2 Balloon P + Vol for this balloon? __________ __________	Draw squished balloon with smaller volume. 16. As volume decreased, ______________________

17. The Pressure and Volume ____

18. What would happen to the pressure inside the Charlie Balloon if I glued my hands to the balloon, and used my manly arms to stretch out to a larger volume?

20. Draw this graph…

21. ____

22. P x V = C, that means that the ______________ X ________________ = _______________________

23. For this gas sample, every single point, every P x V = ___________________________________

24. Same idea, new gas. *Your* nitrogen sample has volume of 3.75 Liters at pressure of 125 kPa.
What is the gas constant for your gas?

25. What if we change the conditions of your nitrogen gas sample, to 9.75 Liters. Calculate the new volume?

26. For any sample of gas, the pressure and volume are inversely proportional and equal to a constant, so…

27. Boyle's Law is part of the ____

28. At constant temperature, a sample of neon gas is at standard pressure and 45.8 liters volume.
If pressure doubles, what is the new volume?

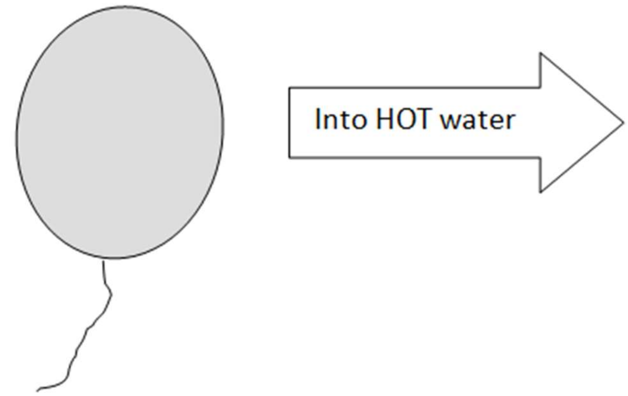
Do the math with kPa here

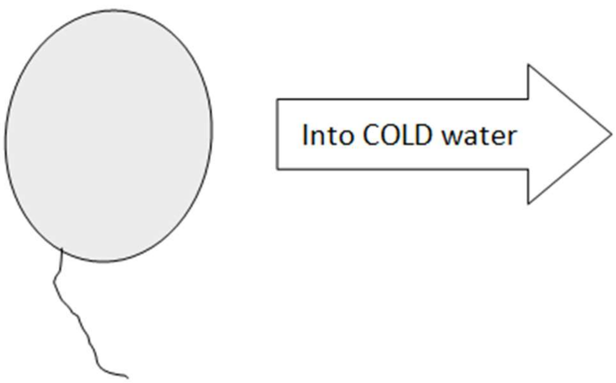
Do the math with atm here

29. At constant temperature, a thick rubber balloon has 16.3 L of $SO_{2(G)}$ at 1.25 atm. The balloon is squished when you sit on it, to 12.8 L. What's the new balloon pressure?

30. Variables to measure gases…		Units	
1			
2			
3			
4			

31. Let’s imagine what happens to the balloon size (volume) when we put these 2 balloons into hot water, and into cold water. What do you think? ________________________________

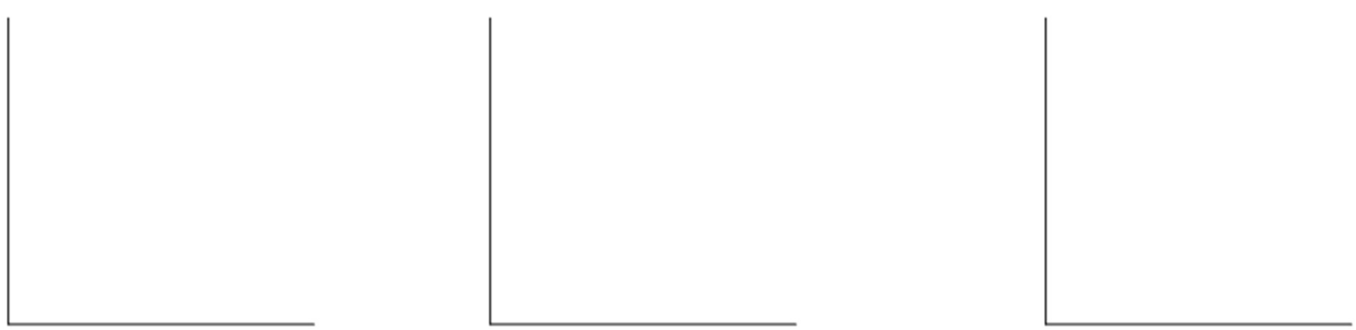




32. When both variables move in the same direction (both increase, or both decrease) this is called being

____

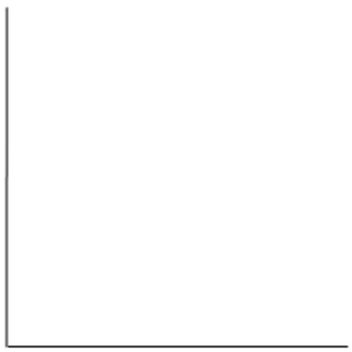
Draw these 3 graphs. (title, axis labels)



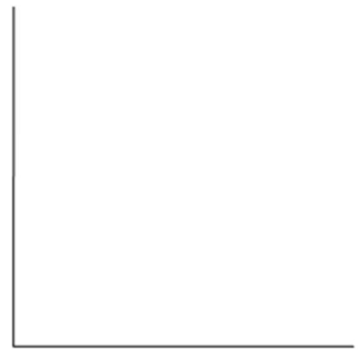
33. Volume and Temperature of a gas are ____

34. Draw these 2 graphs carefully - Note the TITLE wording and the axis labels. (Y is a function of X)

Temperature as a function of Volume



Volume as a function of Temperature



35. Ideal vs. Real Gases

This will be out there, but you are smart enough to grasp this. To teach we discuss “ideal gases”, which are not real. They are the theoretical concept of gases. There are NO examples of ideal gases, any more than there is a Superman or Wonder Woman. We understand them, but we know they are fake.

They are used to help kids learn what gases are, how gases remain gases, etc. There are NO examples of ideal gases. There are many examples of real gases, and you know lots of them, like: oxygen, nitrogen, carbon dioxide, helium, etc.

A.

B.

C.

D.

E.

36. Real gases act most ideally under these conditions:

Because…

37. How ideal are these gases?	Symbol	Number of atoms per particle	ranking
neon	Ne		
carbon dioxide	CO_2		
propane	C_3H_8		

38. If you had 2.45 liters of $CH_{4(G)}$, $NH_{3(G)}$ and $Ar_{(G)}$ at the same temp + pressure, which gas would be MOST IDEAL?

39. Convert 1.06 atm into millimeters of mercury

40. Change 844 mm of Hg into kilopascals

41. A gas in a *rigid cylinder* containing methane gas at 273 K and 125 kPa is warmed to 295 K. What is the new pressure of this gas? *What does a rigid cylinder imply?*

On this side do the math without volume (constant volume)	On this side do the math with the SAME volume, use 22.4 liters (just to be sure)
$\frac{P_1}{T_1} = \frac{P_2}{T_2}$	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

42. Avogadro's Hypothesis

43. Fill in	He	CO_2	NH_3	ANY GAS
Volume				
Temp				
Pressure				
# moles				
# particles				

44. If you have 5.48 liters of $He_{(G)}$ and $CO_{2(G)}$ and $NH_{3(G)}$ all at STP, how many moles of each gas, and how many particles of each gas are present?

45. Under which conditions of temperature + pressure does carbon dioxide gas behave most like an ideal gas?

1. low temperature + low pressure
2. low temperature + high pressure
3. high temperature + low pressure
4. high temperature + high pressure

46. Which gas sample at STP has the same total number of molecules as 2.0 liters of $CO_{2(G)}$ at STP?

1. 5.0 L of $CO_{2(G)}$
2. 2.0 L of $Cl_{2(G)}$
3. 3.0 L of $H_2S_{(G)}$
4. 6.0 L of $He_{(G)}$

47 write the combined gas law
48. State the relationship between pressure and volume? Pressure and volume are… (1) directly proportional (2) indirectly proportional (3) reversely proportional (4) inversely proportional
49. State the relationship between pressure and temperature. Pressure and temperature are…
50. State the relationship between volume and temperature. Volume and temperature are…

51. The KINETIC MOLECULAR THEORY AKA the ____________________ (know this, or else)	
A	
B	
C	
D	
E	

52. Draw these three graphs (careful title to axis label placement!) (PxV) (PxT) (VxT)

53. According to the kinetic molecular theory, the particles of an ideal gas

1. have no potential energy
2. are separated by great distances, compared to their size
3. have strong intermolecular forces
4. are arranged in a regular, repeated geometric pattern

54. Which temperature change would cause a sample of an ideal gas to double in volume while the pressure is held constant? From

1. 400. K to 200. K
2. 200. K to 400. K
3. 400.°C to 200.°C
4. 200.°C to 400.°C

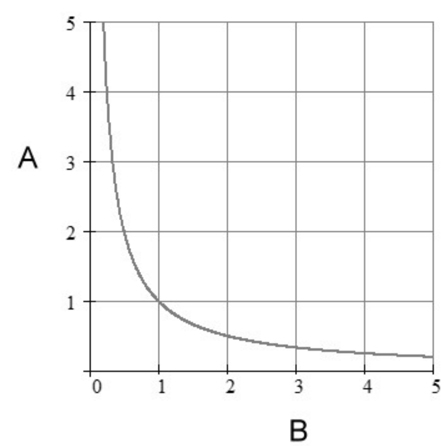
55. A sample of gas confined in a cylinder with a movable piston is kept at constant pressure. The volume of the gas doubles when the temperature of the gas is changed from

1. 400. K to 200. K
2. 200. K to 400. K
3. 400.°C to 200.°C
4. 200.°C to 400.°C

56. Under which conditions of temperature and pressure would a 1-liter sample of a real gas behave most like an ideal gas? 1. 100 K + 0.1 atm 2. 100 K + 10 atm 3. 500 K + 0.1 atm 4. 500 K + 10 atm

57. Here is a graph from gas chemistry. What relationship can it represent?

1. Pressure as a function of Volume
2. Pressure as a function of Temperature
3. Volume as a function of Temperature
4. Temperature as a function of Kinetic Energy



58. What's the volume of a gas at 2.00 atm & 360. K, if it's original conditions were 307 L, 385 K, 0.250 atm?

59. Under which conditions of temperature and pressure would a 1-liter sample of a real gas behave LEAST like an ideal gas?

1. 356 K & 1.2 atm
2. 356 K & 4.0 atm
3. 459 K & 1.2 atm
4. 500 K & 4.0 atm

☺

Gas Chemistry

Combined Gas Law, Boyle in a Bottle Lab, 44 Gas problems,
Gas HW's, Directly or Inversely Proportional,
Avogadro's Hypothesis, Pressure conversion math,
the 4 Variables to measure gases, and
the Kinetic Molecular Theory.