

Regents Chemistry: Dr. Shanzer

## Practice Packet

## Chapter 5: Gases



## 'Gas Laws' Regents Vocabulary

1. Vapor Pressure (Table H) - the pressure of the vapor above a liquid. The vapor is created by evaporation and will increase as the temperature of the liquid increases.
2. Boiling Point - the temperature at which the vapor pressure above a liquid becomes equal to the atmospheric pressure on the liquid. When these conditions exist the liquid will turn to gas and begin boiling.
3. Normal Boiling Point-the temperature of boiling at standard pressure. (dotted line on Table $H$ )
4. Gas Pressure - gases create pressure when the particles collide with the surface of an object.
5. Atmospheric Pressure - the pressure created by Earth's atmosphere equal to 1 atm or 101.3 kPa .
6. Barometer - an instrument designed to measure the air pressure.
7. Standard Temperature and Pressure (STP) - A specific set of conditions equal to 1 atm and 273 Kelvin. (Listed on Table A)
8. Inverse Relationship - a relationship where the variables change in the opposite way...if one variable doubles the other will be cut in half. This relationship never reaches zero.

9. Direct Relationship - a relationship where the variables change in the same way...if one variable doubles so does the other.

10. Combined Gas Law - a mathematical relationship that compares the same gas under two different pressures, volumes and temperatures.

$$
\frac{P_{1} \underline{V}_{1}}{T_{1}}=\frac{P_{2} \underline{V}_{2}}{T_{2}}
$$

11. Avogadro's hypothesis - gases will contain the same number of particles they have the same pressure, temperature and volume.
12. Kinetic Molecular Theory of Gases - a theory used explain the movement and behavior of gases

- Gas particles move in random straight line motion
- Gas particles have elastic collisions where energy is transferred and not lost
- Gas particles have no volume
- Gas particles have no attractive forces

13. Ideal Gas - a theoretical model of the 'perfect' gas that will obey the gas laws exactly because its particles hypothetically have no volume and no attractive forces. IT IS NOT REAL.
14. Real Gas - actual gas particles do have volume and as a result there are attractive forces between particles. When gas particles become cooler and closer together they deviate from ideal gas behavior.

## The Kinetic Molecular Theory (KMT), <br> Ideal vs Real gases <br> \& <br> Avogadro's Hypothesis

Chemistry 200
Video Lesson 5.1

## Objective:

How do we use the Kinetic Molecular Theory (KMT) to explain the behavior of gases, ideal vs. real?

How does Avogadro's Hypothesis help us determine the number of gas particles present?

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I. Kinetic Molecular Theory - KMT
    (predicts behavior of ideal gas molecules: pressure, volume, temp., velocity,
        frequency & forces of collisions)
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A. Gas particles are in constant, random straight-line motion
B. Gas particles collide w/ each other \& the walls of its container. These collisions are what create pressure. The collisions are also elastic, meaning there is no loss of energy.
C. Gas particles have no intermolecular forces of attraction, therefore they do not attract or repel each other.
D. Gas particles have mass but no volume. They are very far apart from each other \& relative to their small size, have volume that is negligible.
E. The absolute temperature (Kelvin) of an ideal gas is directly proportional to its average kinetic energy.

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II. Ideal Gases vs. Real Gases
    A. KMT is a model & talks about gases as if they're ideal (perfect)
    B. Real gases (particles) do not behave exactly as KMT describes
        because of:
    1. Increasing mass (the heavier the gas, the less ideal it is)
    2. Increasing polarity
    (attractive forces are so small they can be disregarded except
        during extreme conditions)
    ex: }\mp@subsup{\textrm{H}}{2}{}\textrm{O}\mathrm{ molecules in the
        atmosphere attract each other
        when temp is cold enough
        \rightarrow \text { rain or snow is formed}
    .
```

C. The 2 real gases that act most like an ideal gas are
Hydrogen $\left(\mathbf{H}_{2}\right) \&$ Helium $(\mathrm{He}) \rightarrow$ they are the lightest
D. Most ideal situation for gases is:

| $\frac{\text { High Temperature }}{\text { lots of molecules }}$ | $\&$ | Low Pressure <br> moving around of room to move |
| :--- | :--- | :--- |
|  | PLIGHT |  |

E. Deviations or changes from what is accepted from the gas laws occur because KMT is not perfect
III. Avogadro's Hypothesis

- equal volumes of all gases under the same temp. \& pressure conditions contain equal numbers of molecules or particles




## Objectives

- Describe the three factors that affect gas pressure.
- Describe the relationships among the temperature, pressure and volume of a gas.



## Properties of Gases

These properties of gases are used to predict how a gas might behave.



## Volume - Temperature Relationship

- As temperature decrease, volume decrease
- DIRECT
- Charles' Law



> The Combined Gas Law
> vamomenss

Objectives

- Use the combined gas law to solve problems.


## Combined Gas Law

- Temperature must be in Kelvin!
- If we are changing all known variables for a gas, we can predict how one of these variables changes. The wording of the question is KEY!


## Table T

## Combined Gas Law

$|$| $\frac{P_{1} V_{1}}{T_{1}}=\frac{P_{2} V_{2}}{T_{2}}$ | $P=$ pressure <br> $V=$ volume <br> $T=$ temperature |
| :--- | :--- |


|  | $T_{1}$ | $T_{2}$ | $T=$ temperature |
| :--- | :--- | :--- | :--- |
|  |  |  |  |

## Standard Temperature \& Pressure (STP)

Table $\mathbf{A}$
Standard Temperature and Pressure

| Name | Value | Unit |
| :---: | :---: | :--- |
| Standard Pressure | 101.3 kPa <br> 1 atm | kilopascal <br> atmosphere |
| Standard Temperature | 273 K <br> $0^{\circ} \mathrm{C}$ | kelvin <br> degree Celsius |

## Example - Temperature is Constant

- A student collected 35.0 ml of a gas at 2.5 atm . If the temperature remains constant, what volume will the gas occupy when the pressure is changed to 3.5 atm ?

Combined Gas Law

$P=$ pressure $V=$ volume $T=$ temperature

$$
\frac{(2.5 \mathrm{at} / \mathrm{m})(35.0 \mathrm{~L})}{(3.5 \mathrm{at} / \mathrm{m})}=\frac{(3.5 \mathrm{~atm})\left(\mathrm{V}_{2}\right)}{(3.5 \mathrm{~atm})}
$$

$$
25 \mathrm{~L}=\mathrm{V}_{2}
$$

## Example - Volume is Constant

- A sample of gas occupies 10.0 L at 1.5 atm and 300 $K$. Calculate the pressure if the temperature is changed to 400 K while the volume remains constant.

Combined Gas Law $\left\lvert\, \frac{P_{1}}{T_{1}}=\frac{P_{2}}{T_{2}} \quad$| $P=$ pressure |
| :--- |
| $V=$ volume |
| $T=$ temperature |\right.

$\frac{1.5 \mathrm{~atm}}{300 \mathrm{~K}}=\frac{\mathrm{P}_{2}}{400 \mathrm{~K}} \quad 2.0 \mathrm{~atm}=\mathrm{P}_{2}$
$\frac{(1.5 \mathrm{~atm})(400 \mathrm{KK})}{300 \mathrm{~K}}=\mathrm{P}_{2}$

## Vapor Pressure \& Table H

Chemistry 200
Video Lesson 5.4

## Objective: <br> How does vapor pressure relate to vaporization? <br> How does table $H$ help us determine vapor pressure, boiling point and strength IMFs?




Sketch Notes

Sketch Notes
$\qquad$

## Boyle's Law - Marshmallow Experiment

Guiding Question: How does a change in pressure affect liquids and gases?

## Figure 1



## Pre-Demonstration Questions

1. What substance is inside the syringe when the plunger is pulled back before the matter sample is placed inside?

Demonstration/ Phenomenon: Record your observations as the plunger is lowered on the two samples of matter.

| Matter | Observations/ Evidence |  |
| :--- | :--- | :--- |
| Water | Pulling Back on Plunger | Pushing Plunger Down |
|  |  |  |
|  |  |  |
|  |  |  |

Model: Draw a model of what is happening as the plunger is lowered on the two samples of matter.


## Questions

1. What happened to the marshmallow when the plunger was pushed down?
2. What happened to the marshmallow when the plunger was pulled back?
3. Which piece of matter was affected by the increase in pressure?
4. Describe the relationship between volume and pressure on a gas (HINT Marshmallow).
5. What other factors might affect the properties of a gas?

|  | D | $\mathrm{R}^{\text {100 }}$ |  | S" |  | H' | $\mathrm{A}^{102}$ | N | $\mathbf{Z}^{\text {™ }} \mid \mathbf{E r}^{\prime \prime}$ |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |

## Video Lesson 1: The Kinetic Molecular Theory \& Ideal vs. Real Gases

1. $\qquad$ According to the kinetic molecular theory for an ideal gas, all gas particles
2. are in random, constant straight-line motion
3. are separated by very small distances relative to their sizes
4. have strong intermolecular forces
5. have collisions that decrease the total energy of the system
6. ___ A sample of chlorine gas is at $300 . \mathrm{K}$ and 1.00 atm . At which temperature and pressure would the sample behave more like an ideal gas?
7. 0 K and 1.00 atm
8. $150 . \mathrm{K}$ and 0.50 atm
9. 273 K and 1.00 atm
10. $600 . \mathrm{K}$ and 0.50 atm
11. According to the kinetic molecular theory, which statement describes the particles of an ideal gas?
12. The gas particles are arranged in a regular pattern.
13. The force of attraction between the gas particles is strong.
14. The gas particles are hard spheres in continuous circular motion.
15. The collisions of the gas particles may result in the transfer of energy.
16. Which statement describes the particle of an ideal gas?
17. The particles move in well-defined, circular paths.
18. When the particles collide, energy is lost.
19. There are forces of attraction between the particles.
20. The volume of the particles is negligible.
21. __ Which gas is least likely to obey the ideal gas laws at very high pressures and very low temperatures?
22. He
23. Ne
24. Kr
25. Xe
26. Explain why you chose your answer in question \#5.
27. $\qquad$ Which rigid cylinder contains the same number of gas molecules at STP as a 2.0-liter rigid cylinder containing $\mathrm{H}_{2(\mathrm{~g})}$ at STP?
28. 1.0-L cylinder of $\mathrm{O}_{2(\mathrm{~g})}$
29. $2.0-\mathrm{L}$ cylinder of $\mathrm{CH}_{4(\mathrm{~g})}$
30. 1.5-L cylinder of $\mathrm{NH}_{3(\mathrm{~g})}$
31. $4.0-\mathrm{L}$ cylinder of $\mathrm{He}_{(\mathrm{g})}$
32. You are given two equally sized containers of $\mathrm{He}_{(\mathrm{g})}$ and $\mathrm{H}_{2(\mathrm{~g})}$ that both behave as ideal gases and have equal pressures and temperatures.
33. Does each container have the same number of particles? Explain.
$\qquad$
$\qquad$
34. Do they have the same number of atoms? Explain.
$\qquad$
$\qquad$
35. Do they have the same mass? Explain.
$\qquad$
$\qquad$

Video Lesson 2: Properties of Gases

Boyle's Law: Class Activity

| Barometric Pressure: 14.6 psi |  |  |
| :--- | :--- | :--- |
| Gauge Pressure | Volume of Air <br> in Syringe | Total <br> Pressure |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |



Figure 4.
Figure 3.


As the pressure increases the volume $\qquad$ (increases/decreases)
http://mintzchemistry.weebly.com

1. ___ Which graph best represents the pressure-volume relationship of an ideal gas at constant temperature?
1) 


2)

3)

4)

2. $\qquad$ Which graph represents the pressure-temperature relationship of an ideal gas at constant volume?


## Video Lesson 3: The Combined Gas Law

1. What is the new volume of a gas if 50.0 ml at 81.0 kPa has its pressure increased to 101.3 kPa while temperature remains constant?
2. 720.0 mL of $\mathrm{H}_{2}$ gas at $0^{\circ} \mathrm{C}$ and 126.6 kPa is changed to STP. What will be its new volume?

3. 440.0 mL of $\mathrm{N}_{2}$ gas at $127.0^{\circ} \mathrm{C}$ is cooled to $27.0^{\circ} \mathrm{C}$, while its pressure is kept constant. What is the new volume?
4. $1,400.0 \mathrm{~L}$ of $\mathrm{N}_{2}$ gas at a pressure of 1.25 atm has its pressure changed to 17.5 atm at constant temperature. What will be its new volume at the pressure?
5. $\mathrm{H}_{2}$ gas occupies a volume of 400.0 mL at $27.0^{\circ} \mathrm{C}$. Find the volume it will occupy if the temperature is increased to $57.0^{\circ} \mathrm{C}$ at constant pressure?
6. What is the pressure that must be exerted on 300.0 mL of a gas, which has been collected at STP so that it may be confined to a volume of 190.0 mL ?
7. If 260.0 mL of $\mathrm{O}_{2}$ gas is collected at $21^{\circ} \mathrm{C}$ and 101.3 kPa , what volume would this gas occupy at STP?
8. 65.0 L of a gas at $52^{\circ} \mathrm{C}$ is to be expanded to 72.0 L . To what temperature must this gas be changed if pressure is kept constant?
9. A student collected 20.0 mL of a gas at 96 kPa . IF the temperature remains constant, what volume will the gas occupy when the pressure is changed to 112 kPa ?
10. What is the volume of 482 liters of gas if the temperature of the gas is changed from standard temperature to $27.0^{\circ} \mathrm{C}$ while the pressure is held constant?

## Video Lesson 4: Vapor Pressure \& Table H

Use Table H to answer the following questions:

1. $\qquad$ At which temperature is the vapor pressure of ethanol equal to $80 . \mathrm{kPa}$ ?
2. $48^{\circ} \mathrm{C}$
3. $73^{\circ} \mathrm{C}$
4. $80^{\circ} \mathrm{C}$
5. $101^{\circ} \mathrm{C}$
6. $\qquad$ Which statement concerning propanone and water at $50^{\circ} \mathrm{C}$ is true?
7. Propanone has a higher vapor pressure and stronger intermolecular forces than water.
8. Propanone has a higher vapor pressure and weaker intermolecular forces than water.
9. Propanone has a lower vapor pressure and stronger intermolecular forces than water.
10. Propanone has a lower vapor pressure and weaker intermolecular forces than water.

11. Which of the substances has the lowest boiling point? $\qquad$
12. Which of the substances has a normal boiling point of $100^{\circ} \mathrm{C}$ ? $\qquad$
13. Which of the substances has the highest boiling point?
14. Which of the substances has the highest vapor pressure at $40^{\circ} \mathrm{C}$ ? $\qquad$
15. Which of the substances has a normal boiling point of $79^{\circ} \mathrm{C}$ ? $\qquad$
16. At what temp. will ethanol boil when the atmospheric pressure is 50 kPa ? $\qquad$
17. At what atmospheric pressure will propanone boil at $20^{\circ} \mathrm{C}$ ? $\qquad$
18. At what atmospheric pressure will water boil at $90^{\circ} \mathrm{C}$ ? $\qquad$
19. Which of the substances above has the lowest vapor pressure at $70^{\circ} \mathrm{C}$ ? $\qquad$
20. As the pressure decreases, the boiling point of water (a) increases, (b) decreases, (c) remains the same.
21. What is the vapor pressure of water at $60^{\circ} \mathrm{C}$ ? $\qquad$
22. At $50^{\circ} \mathrm{C}$, which substance has the strongest intermolecular forces of attraction? Explain.
$\qquad$
$\qquad$
23. According to the kinetic molecular theory for an ideal gas, all gas particles
A) are in random, constant, straight-line motion
B) are separated by very small distances relative to their sizes
C) have strong intermolecular forces
D) have collisions that decrease the total energy of the system
24. Under which conditions of temperature and pressure does a real gas behave most like an ideal gas?
A) low temperature and low pressure
B) low temperature and high pressure
C) high temperature and low pressure
D) high temperature and high pressure
25. A sample of chlorine gas is at $300 . \mathrm{K}$ and 1.00 atmosphere. At which temperature and pressure would the sample behave more like an ideal gas?
A) 0 K and 1.00 atm
B) $150 . \mathrm{K}$ and 0.50 atm
C) 273 K and 1.00 atm
D) $600 . \mathrm{K}$ and 0.50 atm
26. According to the kinetic molecular theory, which statement describes the particles of an ideal gas?
A) The gas particles are arranged in a regular pattern.
B) The force of attraction between the gas particles is strong.
C) The gas particles are hard spheres in continuous circular motion.
D) The collisions of the gas particles may result in the transfer of energy.
27. According to the kinetic molecular theory, the particles of an ideal gas
A) have no potential energy
B) have strong intermolecular forces
C) are arranged in a regular, repeated geometric pattern
D) are separated by great distances, compared to their size
28. Which statement describes the particles of an ideal gas?
A) The particles move in well-defined, circular paths.
B) When the particles collide, energy is lost.
C) There are forces of attraction between the particles.
D) The volume of the particles is negligible.
29. Standard pressure is equal to
A) 1 atm
B) 1 kPa
C) 273 atm
D) 273 kPa
30. According to the kinetic molecular theory, the molecules of an ideal gas
A) have a strong attraction for each other
B) have significant volume
C) move in random, constant, straight-line motion
D) are closely packed in a regular repeating pattern
31. Which diagram best represents a gas in a closed container?
A)

B)

C)

D)

32. The concept of an ideal gas is used to explain
A) the mass of a gas sample
B) the behavior of a gas sample
C) why some gases are monatomic
D) why some gases are diatomic
33. An assumption of the kinetic theory of gases is that the particles of a gas have
A) little attraction for each other and a significant volume
B) little attraction for each other and an insignificant volume
C) strong attraction for each other and a significant volume
D) strong attraction for each other and an insignificant volume
34. A real gas behaves least like an ideal gas under the conditions of
A) low temperature and low pressure
B) low temperature and high pressure
C) high temperature and low pressure
D) high temperature and high pressure
35. A real gas behaves more like an ideal gas when the gas molecules are
A) close and have strong attractive forces between them
B) close and have weak attractive forces between them
C) far apart and have strong attractive forces between them
D) far apart and have weak attractive forces between them
36. Which gas is least likely to obey the ideal gas laws at very high pressures and very low temperatures?
A) He
B) Ne
C) Kr
D) Xe
37. Under the same conditions of temperature and pressure, which of the following gases would behave most like an ideal gas?
A) $\mathrm{He}(\mathrm{g})$
B) $\mathrm{NH}_{3}(\mathrm{~g})$
C) $\mathrm{Cl}_{2}(\mathrm{~g})$
D) $\mathrm{CO}_{2}(\mathrm{~g})$
38. Which two samples of gas at STP contain the same total number of molecules?
A) 1 L of $\mathrm{CO}(\mathrm{g})$ and 0.5 L of $\mathrm{N}_{2}(\mathrm{~g})$
B) 2 L of $\mathrm{CO}(\mathrm{g})$ and $0.5 \mathrm{~L}^{\text {of }} \mathrm{NH}_{3}(\mathrm{~g})$
C) 1 L of $\mathrm{H}_{2}(\mathrm{~g})$ and 2 L of $\mathrm{Cl}_{2}(\mathrm{~g})$
D) 2 L of $\mathrm{H}_{2}(\mathrm{~g})$ and 2 L of $\mathrm{Cl}_{2}(\mathrm{~g})$
39. The table below shows data for the temperature, pressure, and volume of four gas samples.

Data for Four Gas Samples

| Gas <br> Sample | Temperature <br> $(\mathrm{K})$ | Pressure <br> $(\mathrm{atm})$ | Volume <br> $(\mathrm{mL})$ |
| :---: | :---: | :---: | :---: |
| A | 100. | 2 | 400. |
| B | 200. | 2 | 200. |
| C | 100. | 2 | 400. |
| D | 200. | 4 | 200. |

Which two gas samples have the same total number of molecules?
A) $A$ and $B$
B) $A$ and $C$
C) $B$ and $C$
D) $B$ and D
18. A $220.0-\mathrm{mL}$ sample of helium gas is in a cylinder with a movable piston at 105 kPa and 275 K . The piston is pushed in until the sample has a volume of 95.0 mL . The new temperature of the gas is $310 . \mathrm{K}$. What is the new pressure of the sample?
A) 51.1 kPa
B) 216 kPa
C) 243 kPa
D) 274 kPa
19. Each stoppered flask below contains 2 liters of a gas at STP.


Each gas sample has the same
A) density
B) mass
C) number of molecules
D) number of atoms
20. The diagrams below represent three 1-liter containers of gas, $A, B$, and $C$. Each container is at STP.


Which statement correctly compares the number of molecules in the containers?
A) Container $A$ has the greatest number of molecules.
B) Container $B$ has the greatest number of molecules.
C) Container $C$ has the greatest number of molecules.
D) All three containers have the same number of molecules.
21. A cylinder with a movable piston contains a sample of gas having a volume of 6.0 liters at 293 K and 1.0 atmosphere. What is the volume of the sample after the gas is heated to 303 K , while the pressure is held at 1.0 atmosphere?
A) 9.0 L
B) 6.2 L
C) 5.8 L
D) 4.0 L
22. At which temperature is the vapor pressure of ethanol equal to the vapor pressure of propanone at $35^{\circ} \mathrm{C}$ ?
A) $35^{\circ} \mathrm{C}$
B) $60 .{ }^{\circ} \mathrm{C}$
C) $82^{\circ} \mathrm{C}$
D) $95^{\circ} \mathrm{C}$
23. A gas occupies a volume of 444 mL at 273 K and 79.0 kPa . What is the final kelvin temperature when the volume of the gas is changed to 1880 mL and the pressure is changed to 38.7 kPa ?
A) 31.5 K
B) 292 K
C) 566 K
D) 2360 K
24. Which temperature change would cause the volume of a sample of an ideal gas to double when the pressure of the sample remains the same?
A) from $200^{\circ} \mathrm{C}$ to $400^{\circ} \mathrm{C}$
B) from $400^{\circ} \mathrm{C}$ to $200^{\circ} \mathrm{C}$
C) from 200 K to 400 K
D) from 400 K to 200 K
25. Which graph represents the relationship between pressure and volume for a sample of an ideal gas at constant temperature?
A)


Volume
B)

C)

D)


## Volume

26. A gas occupies a volume of 40.0 milliliters at $20^{\circ} \mathrm{C}$. If the volume is increased to 80.0 milliliters at constant pressure, the resulting temperature will be equal to
A) $20^{\circ} \mathrm{C} \times \frac{80.0 \mathrm{~mL}}{40.0 \mathrm{~mL}}$
B) $20^{\circ} \mathrm{C} \times \frac{40.0 \mathrm{~mL}}{80.0 \mathrm{~mL}}$
C) $293 \mathrm{~K} \times \frac{80.0 \mathrm{~mL}}{40.0 \mathrm{~mL}}$
D) $293 \mathrm{~K} \times \frac{40.0 \mathrm{~mL}}{80.0 \mathrm{~mL}}$
27. As the temperature of a given sample of a gas decreases at constant pressure, the volume of the gas
A) decreases
B) increases
C) remains the same
28. A cylinder with a tightly fitted piston is shown in the diagram below.


As the piston moves downward, the number of molecules of air in the cylinder
A) decreases
B) increases
C) remains the same
29. Which changes in pressure and temperature occur as a given mass of gas at 50.6 kPa and 546 K is changed to STP?
A) The pressure is doubled and the temperature is halved.
B) The pressure is halved and the temperature is doubled.
C) Both the pressure and the temperature are doubled.
D) Both the pressure and the temperature are halved.
30. The graph below represents the relationship between pressure and volume of a given mass of a gas at constant temperature.


The product of pressure and volume is constant. According to the graph, what is the product in atmmL?
A) 20 .
B) 40 .
C) 60 .
D) 80 .
31. Base your answer to the following question on the information below and on your knowledge of chemistry.

The diagram below represents a cylinder with a movable piston. The cylinder contains 1.0 liter of oxygen gas at STP. The movable piston in the cylinder is pushed downward at constant temperature until the volume of $02(\mathrm{~g})$ is 0.50 liter.


State the effect on the frequency of gas molecule collisions when the movable piston is pushed farther downward into the cylinder.
32. Base your answer to the following question on the information below and on your knowledge of chemistry.

A few pieces of dry ice, $\mathrm{CO}_{2}(\mathrm{~s})$, at $-78^{\circ} \mathrm{C}$ are placed in a flask that contains air at $21^{\circ} \mathrm{C}$. The flask is sealed by placing an uninflated balloon over the mouth of the flask. As the balloon inflates, the dry ice disappears and no liquid is observed in the flask.
Write the name of the process that occurs as the dry ice undergoes a phase change in the flask.
Base your answers to questions $\mathbf{3 3}$ through $\mathbf{3 5}$ on the information below.

A sample of helium gas is in a closed system with a movable piston. The volume of the gas sample is changed when both the temperature and the pressure of the sample are increased. The table below shows the initial temperature, pressure, and volume of the gas sample, as well as the final temperature and pressure of the sample.

Helium Gas in a Closed System

| Condition | Temperature <br> $(\mathrm{K})$ | Pressure <br> $(\mathrm{atm})$ | Volume <br> $(\mathrm{mL})$ |
| :--- | :---: | :---: | :---: |
| initial | 200. | 2.0 | 500. |
| final | 300. | 7.0 | $?$ |

33. Compare the total number of gas particles in the sample under the initial conditions to the total number of gas particles in the sample under the final conditions.

## Gas Law Review

34. Convert the final temperature of the helium gas sample to degrees Celsius.
35. In the space below show a correct numerical setup for calculating the final volume of the helium gas sample.

Base your answers to questions $\mathbf{3 6}$ through $\mathbf{3 8}$ on the information below and on your knowledge of chemistry.
Cylinder $A$ has a movable piston and contains hydrogen gas. An identical cylinder, $B$, contains methane gas. The diagram below represents these cylinders and the conditions of pressure, volume, and temperature of the gas in each cylinder.

Cylinder A


Cylinder B

36. Show a numerical setup for calculating the volume of the gas in cylinder $B$ at STP.
37. State a change in temperature and a change in pressure that will cause the gas in cylinder $A$ to behave more like an ideal gas.
38. Compare the total number of gas molecules in cylinder $A$ to the total number of gas molecules in cylinder $B$.

Base your answers to questions 39 through 41 on the information below.
A rigid cylinder is fitted with a movable piston. The cylinder contains a sample of helium gas, $\mathrm{He}(\mathrm{g})$, which has an initial volume of 125.0 milliliters and an initial pressure of 1.0 atmosphere, as shown below. The temperature of the helium gas sample is $20.0^{\circ} \mathrm{C}$.

39. Helium gas is removed from the cylinder and a sample of nitrogen gas, $\mathrm{N}_{2}(\mathrm{~g})$, is added to the cylinder. The nitrogen gas has a volume of 125.0 milliliters and a pressure of 1.0 atmosphere at $20.0^{\circ} \mathrm{C}$. Compare the number of particles in this nitrogen gas sample to the number of particles in the original helium gas sample.
40. The piston is pushed further into the cylinder. In the space below, show a correct numerical setup for calculating the volume of the helium gas that is anticipated when the reading on the pressure gauge is 1.5 atmospheres. The temperature of the helium gas remains constant.
41. Express the initial volume of the helium gas sample, in liters.

