**SCIENCE 8 – STATES OF MATTER WORKSHEET**

NAME: ____________________________

<table>
<thead>
<tr>
<th>Vocabulary</th>
<th>Move around quickly</th>
<th>State of matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contracts</td>
<td>Kinetic molecular theory</td>
<td>Vibrate</td>
</tr>
<tr>
<td>Expands</td>
<td>Mass</td>
<td>Slide past each other</td>
</tr>
<tr>
<td>Faster</td>
<td>Matter</td>
<td>Slower</td>
</tr>
</tbody>
</table>

Use your notes from pages 1 – 2 and the terms in the vocabulary box to fill in the blanks for the following nine questions. You will not need to use every term.

1) ___________ mass ___________ is the amount of matter that makes up something.

2) ___________ volume ___________ is the amount of space that a material takes up.

3) Anything that has mass and volume is called ___________ matter ___________.

4) When you add energy to matter, the particles move ___________ faster ___________ and the matter ___________ expands ___________.

5) Particles in a solid are packed so close together they can only ___________ vibrate ___________.

6) Particles in a liquid can ___________ slide past each other ___________.

7) Particles in a gas can ___________ move around quickly ___________.

8) When you remove energy from particles they move ___________ slower ___________ and the matter ___________ contracts ___________.

9) The ___________ kinetic molecular theory ___________ explains how particles act when their spacing and movement change.

10) Match each Term on the left with the best Descriptor on the right. Each Descriptor may be used only once.

<table>
<thead>
<tr>
<th>Term</th>
<th>Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Mass</td>
</tr>
<tr>
<td>D</td>
<td>Solid</td>
</tr>
<tr>
<td>E</td>
<td>Gas</td>
</tr>
<tr>
<td>A</td>
<td>Matter</td>
</tr>
<tr>
<td>F</td>
<td>Liquid</td>
</tr>
<tr>
<td>B</td>
<td>Volume</td>
</tr>
</tbody>
</table>
Complete the following table to describe three states of matter. The table has been partially completed to help you.

<table>
<thead>
<tr>
<th>Shape</th>
<th>Solid</th>
<th>Liquid</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>fixed shape</td>
<td>Not fixed; takes the shape of the container</td>
<td>not fixed, takes shape of container</td>
</tr>
<tr>
<td>Spaces between particles</td>
<td>very little</td>
<td>very little, but more than solid</td>
<td>not fixed, fills the container</td>
</tr>
<tr>
<td>Movement of particles</td>
<td>vibrate</td>
<td>slide past each other</td>
<td>Can move freely and quickly in all directions in the container</td>
</tr>
</tbody>
</table>

12) Use your knowledge of the kinetic molecular theory to explain the following statements:

(a) Solids have a definite shape because the particles are close to each other and not moving other than vibrating.

(b) Liquids and gases flow because they are no attractive forces keeping the molecules close to each other.

(c) Ice cubes form in the freezer because particles slow down enough causing the water molecules to stick to each other.

(d) Ice cream melts quickly on a hot day because particle gain energy, speed up, causing them to separate.

(e) Gases do not have a definite shape because not enough particles close enough to make a shape. Gas particles move quickly and spread out.
Model 1 Representation of Atoms in Different Phases

http://itl.chem.ufl.edu/2045_s00/lectures/lec_f.html

Key Questions
1. What are the key characteristics of atoms and molecules in gases, liquids, and solids? In Table 1 below, describe the characteristics of particles for each phase of matter based on Model 1. Be specific with regard to spacing, the potential of particles for movement, and whether or not the particles will fill the container.

Table 1. Characteristics of the Phases of Matter

<table>
<thead>
<tr>
<th>SPACING</th>
<th>SOLID</th>
<th>LIQUID</th>
<th>GAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>close</td>
<td>medium</td>
<td>far</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>POTENTIAL FOR MOVEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>vibration</td>
</tr>
<tr>
<td>elastic Sliding</td>
</tr>
<tr>
<td>fast movement</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FILLING A CONTAINER</th>
</tr>
</thead>
<tbody>
<tr>
<td>no</td>
</tr>
<tr>
<td>no</td>
</tr>
<tr>
<td>yes</td>
</tr>
</tbody>
</table>
2. In which phase of matter is there the least spacing between particles?
   Solid

3. In which phase of matter is there the most potential for movement?
   Solid / gas

4. Which phase of matter does not have a definite shape yet the particles will not fill the container?
   Liquid

5. In terms of spacing, what would be necessary to change from a solid to a liquid? What is this process called and how is this accomplished?
   Spread out \rightarrow add heat, melting / fusion

6. In terms of spacing, what would be necessary to change a liquid to a gas? What is this process called and how is this accomplished?
   Spread out \rightarrow add heat, evaporation

7. In terms of spacing, what would be necessary to change a liquid to a solid? What is this process called and how is this accomplished?
   Condense \rightarrow remove heat, freezing / solidification

**Model 2**

**POSTULATE OF THE KINETIC MOLECULAR THEORY**

1. Gases consist of tiny particles (atoms or molecules).
2. These particles are so small, compared with the distances between them that the volume (size) of the individual particles can be assumed to be negligible (zero).
3. The particles are in constant random motion, colliding with the walls of the container. These collisions with the walls cause the pressure exerted by the gas.
4. The particles are assumed to not attract or repel each other.
5. The average kinetic energy of the gas particles is directly proportional to the Kelvin temperature of the gas.
Key Questions
1. What causes a gas to exert pressure when confined in a container?

   Collisions with walls of container

2. How does the total volume of gas particles compare to the volume of the space between the gas particles?

   Space between gas particles is basically zero

3. As the temperature of a gas decreases, what change occurs in the amount of kinetic energy?

   It decreases (direct relationship)

4. What property of gas particles is measured by temperature?

   Average kinetic energy

5. What is the relationship between temperature and molecular motion?

   Direct

6. In terms of the kinetic-molecular theory of gases, how can an increase in the temperature of a gas confined in a rigid container cause an increase in the pressure of the gas?

   The molecules speed up, meaning they will hit into the walls of the container more often, increasing the pressure

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Authored by
Edited by Linda Padwa and David Hanson, Stony Brook University
Applications
1. There is a government warning on all aerosol cans that states: Do not store at a temperature above 120° F (50°C).

a) Explain why this warning is required in terms of the relationship between temperature and pressure and the kinetic molecular theory.

As the temperature increases the molecules move more quickly, hitting the walls of the container more often, increasing the pressure.

b) What could happen if the can were to be heated above 120° F (50°C)?

It would explode.

2. What would happen to a completely inflated balloon if it were taken from inside a house to the outside in the middle of January in Minnesota? Explain this prediction in terms of the Kinetic Molecular Theory.

It would decrease in volume because the particles slow down, hitting the walls of the balloon less often, making inside pressure lower than outside pressure, allowing the balloon to shrink.

3. Why do the manufacturers of tires suggest that tire pressure be checked before a car has been driven any distance?

If the tire is too full, driving long distances will cause the tires to heat up, causing too much pressure on the inside, causing a blown tire.
POGIL: Pressure

Name:

Group Members:

Objective:

Explain and define pressure and how it relates to and applies to the gaseous state.
Explain how the quantity, temperature, and volume of the container affect gas pressure.
Explain the effect of changes in quantity, pressure, and temperature on the pressure exerted by a gas sample.

Model I: Gas Molecules and Pressure

All gases exert pressure.
At any point, a gas exerts an equal pressure in all directions at any point within a gas.
Pressure is defined as the force per unit area.

Please note the diagram showing a sample of gas molecules enclosed in a container. The arrows indicate the velocities of the molecules.

Key Questions:

1. How do the gas molecules move in a sample of a gas? (Circle your choices below.)
   a. Relative to the molecules of a solid or liquid, do they move quickly or slowly?
   b. Do they move in an organized fashion or in random motion?
   c. Do they move in a straight line or in a zig-zag pattern?

2. The motion of a gas molecule is usually stopped by collision with two different things. Based on the diagram in the above model, what are those two things?
   Other molecules and the sides of the container

3. Somewhat gently, make a fist with one hand and “collide” it with the palm of your other hand. What does a collision cause to be exerted?
   Pressure

4. It is true that collisions of gas molecules cause pressure. How?
   Yes, when things collide with each other pressure increases.

5. Thinking about the pressure of the gas inside the balloon, in what direction does pressure act?
   Out

6. Why do you think pressure of a gas acts in that “direction”?
   The gas molecules are trying to spread out causing more collisions with the walls of the balloon.

Revised Nov 2011
7. With regard to the two items in question 2, the pressure a gas exerts is caused when a gas atom/molecule collides with what single item?

*the walls of the container*

**Model II: The Barometer**

A BAROMETER is a simple piece of equipment used to measure pressure.

A simple barometer is made by obtaining a long tube sealed at one end and filling it completely with mercury. The tube is then inverted and the open end is placed in a dish partially filled with mercury and the tube is held vertically. The mercury in the tube falls to a height, \( h \), determined by the pressure of the air on the surface of the mercury in the dish. There is essentially no pressure in the tube above the mercury.

There are two forces acting on the mercury in the tube - the force of gravity trying to pull it down and the force due to the air pressure pushing up.

**Key Questions:**

8. Why does some of the mercury “fall out” of the barometer tube once it has been inverted?

*force of gravity*

9. Why does all of the mercury not “fall out” of the barometer tube once it has been inverted?

*force of air pressure*

10. Draw in additional arrows to represent a higher level of atmospheric pressure.

a. What happens to the height of the mercury in the barometer tube? Why?

*It would increase because the air pressure would be a greater force than the gravity pushing it down.*

b. What happens to the amount of “near vacuum space” at the top of the barometer tube? Why?

*It would decrease because a greater force is causing the vacuum space to decrease.*

11. What would happen to the height of the mercury in the tube if there was less atmospheric pressure? Why?

*It would decrease because not as great a force would be holding the mercury in.*

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POGIL: Pressure

Model III: Atmospheric Pressure and Altitude

Higher Altitude

Sea Level

Pressure = 1 atm

Lower Altitude

There is something called atmospheric pressure.
The pressure of the atmosphere varies with altitude.
Pressure is still defined as the force per unit area.

Key Questions:

12. The earth's surface is the area over which the force is exerted. What is causing the "force" of the atmospheric pressure?

   the amount of gas molecules above the earth's surface

13. At higher altitudes (above sea level):
   a. there is MORE or LESS atmosphere over the earth's surface, relative to sea level.
   b. there are MORE or LESS collisions over the earth's surface, relative to sea level.
   c. the atmospheric pressure is HIGHER or LOWER than at sea level.
   d. Explain (c)? Since there is less atmosphere, there are less collisions causing the pressure to be LESS

14. At lower altitudes (below sea level):
   a. there is MORE or LESS atmosphere over the earth's surface, relative to sea level.
   b. there are MORE or LESS collisions over the earth's surface, relative to sea level.
   c. the atmospheric pressure is HIGHER or LOWER than at sea level.
   d. Explain (c)? Since there is more atmosphere, there are more collisions causing the pressure to be MORE

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Model IV: Units of Pressure

$\text{millimeter of mercury} = \text{mmHg} = \text{vertical height of mercury in a barometer}$

$torr = \text{pressure needed to support 1 mm of Hg} = 1 \text{ mmHg} \text{ (named for Evangelista Torricelli)}$

$\text{atmosphere} = \text{atm or standard atmosphere} - \text{pressure at sea level at 0°C on a "normal day"; 1 atm = 760. mmHg = 760. torr; the atmosphere can support 760. mm of Hg}$

$pascal = \text{Pa} = \text{SI unit of pressure; very small unit of pressure so kilopascal (kPa) is used}; 1 \text{atm} = 101,325 \text{ kPa} = 101325 \text{ Pa} \text{ (named for Blaise Pascal)}$

$pounds \text{ per square inch} = \text{psi} = \text{describes how many pounds (force) are exerted over a square inch of area}; 1 \text{ atm} = 14.69 \text{ psi}$

Please note the difference between 1 atmosphere of pressure and atmospheric pressure. The first is a constant and the second varies from place to place and even varies over time at the same place. Atmospheric pressure is often referred to as "barometric pressure".

Exercises:
15. Showing all work and using unit analysis, perform the following pressure conversions.
   a. Convert 45.998 kPa to the equivalent pressure in atmospheres.
      \[
      \frac{45.998 \text{ kPa}}{1 \text{ atm}} \times \frac{1 \text{ atm}}{101.3 \text{ kPa}} = 0.45408 \text{ atm}
      \]
   b. Convert 3987 mm Hg to the equivalent pressure in atmospheres.
      \[
      \frac{3987 \text{ mm Hg}}{1 \text{ atm}} \times \frac{1 \text{ atm}}{760 \text{ mm Hg}} = 5.246 \text{ atm}
      \]
   c. Convert 6594 Pa to the equivalent pressure in torr.
      \[
      \frac{6594 \text{ Pa}}{101325 \text{ Pa}} \times \frac{760 \text{ mm Hg}}{1 \text{ atm}} = 49.46 \text{ torr}
      \]
   d. Convert 2.87 kPa to the equivalent pressure in mmHg.
      \[
      \frac{2.87 \text{ kPa}}{101.3 \text{ kPa}} \times \frac{760 \text{ mm Hg}}{1 \text{ atm}} = 21.5 \text{ mm Hg}
      \]

Wrap Up:
16. What causes a gas to have pressure?
   \text{Collisions}

17. To increase the pressure of a gas, you need to increase the collisions. List three things to do to a sample of a gas that would increase the pressure. Explain how each item would increase the pressure.
   \begin{itemize}
   \item Increase temp (the molecules would move more quickly)
   \item Decrease volume (less space to move would mean more collisions)
   \item Increase # of particles (the more particles, the more collisions)
   \end{itemize}
A phase diagram is a graphical way to summarize the conditions under which equilibria exist between the different states of matter. It also allows us to predict the phase of a substance that is stable at any given temperature and pressure.

Critical Thinking Questions

1. What label is on the x-axis?
   - temp

2. What label is on the y-axis?
   - pressure

3. List the three phases of matter that are on the diagram.
   - solid, liquid, gas

4. At which point do all three phases on the diagram meet?
   - triple point

5. In your own words, define what you think the triple point is.
   - when all 3 states of matter are present in equilibrium

6. The line extending from the triple point to the critical point stops. What does this mean in terms of phase change?
   - there is no longer a phase change after that point

7. In your own words, define what you think the critical point is.
   - the point at which liquid and gas can no longer become one another
Model 2

Phase Diagram for Water

Critical Thinking Questions

8. Identify the following points: A, B, C, D
   
   A - triple point       C - sublimation/deposition points
   B - critical point    D - melting/freezing points

9. If the line AD represents the melting/freezing line for water, what would the AB line represent? What would the AC line represent?

   A-C sublimation/deposition line
   AB boiling/condensing line
10. Given the phase diagram above, what phase would water be in if it had the following properties:
   a. 50 °C, and 0.5 atm pressure
      gas
   b. -50°C, and 0.5 atm pressure
      solid
   c. 125 °C, and 1.0 atm pressure
      gas

Model 3

11. In the diagram above, what do (s), (l), and (g) represent?
    solid, liquid, gas

Using the phase diagram of the liquid above, describe any changes in phase present when H2O is:

12. kept at 0°C while the pressure is increased from 1 atm to 5atm (vertical line)
    melting (solid → liquid)

13. Kept at 1.00 atm while the temperature is increased from 0 °C to 125 °C. (horizontal line)
    solid → liquid → gas
    melting, evaporation
Phase Diagram Worksheet

A phase diagram is a graphical way to depict the effects of pressure and temperature on the phase of a substance.

The CURVES indicate the conditions of temperature and pressure under which “equilibrium” between different phases of a substance can exist. BOTH phases exist on these lines:

Melting/Freezing: Any point on this line (pressure & temperature) the substance is both solid and liquid.

Sublimation/Deposition: Any point on this line (pressure & temperature) the substance is both solid and gas.

Vaporization/Condensation: Any point on this line (pressure & temperature) the substance is both liquid and gas.

NOTE: the vapor pressure curve ends at the critical point, the temperature above which the gas cannot be liquefied no matter how much pressure is applied (the kinetic energy simply is too great for attractive forces to overcome). Any substance beyond this critical point is called a supercritical fluid – indistinguishable between gas or liquid (neither one).

The TRIPLE POINT is the condition of temperature and pressure where ALL THREE phases exist in equilibrium (solid, liquid, gas).

Remember that pressure can be expressed in many units where: 1 atm = 101.3 kpa = 760 mmHg

Refer to the phase diagram below when answering the questions on the back of this worksheet:

NOTE: “Normal” refers to STP – Standard Temperature and Pressure.

For chemistry help, visit www.chamfiesta.com

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1) What are the values for temperature and pressure at STP? T= \( 0 \) °C, P= 1.00 atm

2) What is the normal freezing point of this substance? \( 100 \) °C

3) What is the normal boiling point of this substance? \( 325 \) °C

4) What is the normal melting point of this substance? \( 100 \) °C
What is the phase (s, l, g) of a substance at 2.0 atm and 100 °C?
7) What is the phase (s, l, g) of a substance at 0.75 atm and 100 °C?
8) What is the phase (s, l, g) of a substance at 0.5 atm and 50 °C?
9) What is the phase (s, l, g) of a substance at 1.5 atm and 200 °C?
10) What is the phase (s, l, g) of a substance at 1.5 atm and 800 °C?
11) What is the condition of the triple point of this substance? T= 100°C, P= 0.65 atm

12) If a quantity of this substance was at an initial pressure of 1.25 atm and a temperature of 300 °C was lowered to a pressure of 0.25 atm, what phase transition(s) would occur? evaporation
13) If a quantity of this substance was at an initial pressure of 1.25 atm and a temperature of 0 °C was lowered to a pressure of 0.25 atm, what phase transition(s) would occur? sublimation

14) If a quantity of this substance was at an initial pressure of 1.0 atm and a temperature of 200 °C was lowered to a temperature of -200 °C, what phase transition(s) would occur? freezing
15) If a quantity of this substance was at an initial pressure of 0.5 atm and a temperature of 200 °C was lowered to a temperature of -200 °C, what phase transition(s) would occur? deposition

16) If this substance was at a pressure of 2.0 atm, at what temperature would it melt? 190 °C
17) If this substance was at a pressure of 2.0 atm, at what temperature would it boil? It would not

18) If this substance was at a pressure of 0.75 atm, at what temperature would it melt? 100 °C
19) If this substance was at a pressure of 0.75 atm, at what temperature would it boil? 125 °C

20) At what temperature do the gas and liquid phases become indistinguishable from each other? 810 °C
21) At what pressure would it be possible to find this substance in the gas, liquid, and solid phase? 0.65 atm

22) If I had a quantity of this substance at a pressure of 1.00 atm and a temperature of -100 °C, what phase change(s) would occur if I increased the temperature to 600 °C? At what temperature(s) would they occur? (Note: multiple answers needed for this question)
@ 100 °C melting @ 325 °C boiling

22) If I had a quantity of this substance at a pressure of 2.00 atm and a temperature of -150 °C, what phase change(s) would occur if I decreased the pressure to 0.25 atm? At what pressure(s) would they occur? (Note: multiple answers needed for this question)
0.35 atm sublimation
POGIL: Intermolecular Forces

Model 1: What is an intermolecular force?
As you have learned, matter is made up of discrete particles called atoms, which chemically combine to form molecules. Molecules do not exist as independent units: in fact, groups of molecules “stick together” in order to form liquids and solids. The forces that hold groups of molecules together are intermolecular forces. Without intermolecular forces, the world as we know it would not be the same.

Figure 1: Intramolecular and Intermolecular Forces

Critical Thinking Questions:
1. What specific molecule is represented inside each box in Figure 1? Water
2. In relation to the box for molecule 1, where do the intramolecular forces exist in Figure 1 – inside the boxes or outside the boxes? Inside
3. Based on the intramolecular forces for molecule 1, draw similar asterisks (*) for the intramolecular forces on the diagram for molecules 2 and 3.
4. In relation to the molecule, where do intramolecular forces tend to occur – within the molecule or outside of the molecule? Intermolecular
5. Two intermolecular forces exist in Figure 1. Where are they positioned relative to the molecules – within the molecules or between the molecules? Between
6. State the difference between intermolecular and intramolecular forces in terms of where they occur on the molecular level.
   - Intra → within
   - Inter → between
Model 2: What are the three types of intermolecular forces?
There are three different types of intermolecular forces: dipole-dipole interactions, hydrogen bonding (although technically this is not a bond because it does not involve electrons being shared or transferred), and dispersion forces.

Figure 2: Dipole-Dipole Interactions

Critical Thinking Questions:

7. Figure 2 represents an arrangement of five molecules. What is the difference between the two ends of each molecule?

8. Molecules with the property you identified in #7 are known as dipoles. Consult with your group and reach a consensus on what you think a dipole is. Write down this definition.

   A dipole is a difference in charged ends of the molecule

9. Consider the attractive forces shown in Figure 2. In terms of the positive and negative ends of the dipoles, where do attractive forces occur?

   between molecules + and - ends

10. Consider the repulsive forces shown in Figure 2. In terms of the positive and negative ends of the dipoles, where do repulsive forces occur?

    between molecules - and - or + and +

11. The forces described in #9 and #10 are called dipole-dipole interactions. How might dipole-dipole interactions help many molecules attract each other?

    like a magnet, + - attraction

Page 2 of 7
A dipole is most often found in polar molecules, in which the electrons are unevenly shared. This uneven sharing gives one side of the molecule a partially positive charge ($\delta^+$) and the other side a partially negative charge ($\delta^-$).

12. What causes the dipole in polar molecules?
   Uneven sharing of electrons

13. What symbols are used to represent the partial charges at the ends of polar molecules?
   $\delta^-$ $\delta^+$

14. In the diagram below, a hydrogen iodide molecule has been drawn with its partial positive and partial negative charges. Using the three molecules in the box, draw an attractive force between two HI molecules using a dashed line (---) and a repulsive force between two HI molecules using a dotted line (.....).

15. Nonpolar molecules do not form dipoles, because electrons are shared evenly. Would you expect nonpolar molecules to "stick together" more or less effectively than polar molecules?
   Less

16. Explain your answer to #15 in terms of dipole-dipole interactions.
   If there are not strong "magnets" they will not be very attracted to each other
When a hydrogen atom is covalently bonded to nitrogen, oxygen, or fluorine, a very strong dipole is formed. The dipole-dipole interactions that result from these dipoles are known as hydrogen bonding. Hydrogen bonding is an especially strong form of dipole-dipole interaction.

17. Below is a diagram of ammonia. Draw two more ammonia molecules in the box, indicating the partial positive and partial negative ends for each molecule.

18. In the diagram in #17 above, draw the attractive forces between the ammonia molecules with a dotted line (....). Label these forces hydrogen bonds.

19. Indicate and label one covalent bond in the diagram in #17.

20. Is a hydrogen bond the same as a covalent bond?
   No

21. With your group, explain your answer to #20, including:
   a. How a covalent bond is formed.
      SHARING OF ELECTRONS
   b. How a hydrogen bond is formed.
      ATTRACTION BETWEEN $\text{L}^-$ AND $\text{H}^+$ OF MOLECULES
   c. How covalent bonds and hydrogen bonds are similar.
      BETWEEN NON-METALS
   d. How covalent bonds and hydrogen bonds are different.
      WITHIN BETWEEN 23
22. Bob’s sheep like to wander around the pasture. They could be found anywhere at any moment. How are Bob’s sheep distributed in box A?

evenly

23. How are Bob’s sheep distributed in box C? Are the woolly sheep evenly spread in the pasture?

unevenly

24. Looking at the sheep in box C, identify a “woolly” area and a “non-woolly” area. Label the woolly area W and the non-woolly area NW.

25. Now let’s look at the krypton atoms in boxes B and D. Electrons, like sheep, like to wander around the atom.

a. How many protons are in the atom in each box? 18

b. How many electrons are in the atom in each box? 18


yes, \( p^+ = e^- \)
27. In box B, are the electrons evenly distributed around the nucleus? Explain.

Yes

28. In box D, are the electrons evenly distributed around the nucleus? Explain.

No

29. In box D, indicate any area that is crowded with electrons with a "δ−", and any area where the nucleus is exposed with a "δ+".

30. Even though the krypton atom in #29 is electrically neutral, why could it be said to have a "momentary" dipole?

Yes

31. Based on your answer to #30, what do you think helps neutral atoms and nonpolar molecules attract to each other?

momentary dipoles → constant movement of electrons

Read This!

Even though atoms by themselves are electrically neutral, a momentary imbalance of electrons can create a momentary dipole. The dipole-dipole interactions among these momentary dipoles are known as dispersion forces. These forces, also known as van der Waals forces, help neutral atoms and nonpolar molecules attract each other.

32. What causes a dispersion force to occur between two atoms or nonpolar molecules?

movements of electrons

33. How are dispersion forces similar to dipole-dipole interactions?

attraction between Δ− + Δ+

34. How are dispersion forces different to dipole-dipole interactions?

nonpolar ≠ polar
Extension Questions – YES, you must answer these challenge questions as well!

35. What is the difference between the formation of an ion and the formation of a momentary dipole?
   \[ \text{Ion} \rightarrow \text{transfer of electron} \]
   \[ \text{MD} \rightarrow \text{movement of electrons} \]

36. The difference of electronegativity between hydrogen and bromine is 0.7, and the difference in electronegativity between hydrogen and chlorine is 0.9.
   a. Which would exhibit stronger dipole-dipole interactions, HBr or HCl?
      \[ \text{HCl} \]
   b. Justify your answer.
      \[ \text{larger } \mathbf{I}^- \rightarrow \mathbf{I}^+ \]

37. Neon has 10 electrons, and krypton has 18 electrons.
   a. Which element do you think has a greater chance of forming a momentary dipole?
      \[ \text{Krypton} \]
   b. Explain your answer to part (a).
      \[ \text{more electrons to move} \]
   c. Which element do you think exhibits greater dispersion forces?
      \[ \text{Krypton} \]
   d. Explain your answer to part (c).
      \[ \text{more electrons} \]

38. Which intermolecular forces can be found in the following molecules?

![Molecules]
Intermolecular Forces Worksheet

For each of the following compounds, determine the main intermolecular force. You may find it useful to draw Lewis structures for some of these molecules:

1) nitrogen gas  **london dispersion**

2) carbon tetrachloride  **london dispersion**

3) $\text{H}_2\text{S}$  **dipole-dipole**

4) sulfur monoxide  **dipole-dipole**

5) $\text{N}_2\text{H}_2$  **hydrogen bonding**

6) boron trihydride  **london dispersion**

7) $\text{CH}_4\text{O}$  **hydrogen bonding**

8) $\text{SiH}_3\text{O}$  **dipole-dipole**

9) Explain why ethyl alcohol ($\text{C}_2\text{H}_5\text{OH}$) has a higher boiling point ($78.4^\circ\text{C}$) than methyl alcohol ($\text{CH}_3\text{OH}$; $64.7^\circ\text{C}$).

   Both have hydrogen bonding, but ethyl alcohol's mass is larger, making it more difficult to boil

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10) Rank the following by from lowest to highest anticipated boiling point: C$_2$H$_4$, CH$_4$, Ne, H$_2$COCH$_3$.

- D-D
- CH$_4$, Ne, C$_2$H$_4$, H$_2$COCH$_3$

(lowest mass → highest mass)

11) Motor oil largely consists of molecules that consist of long chains of carbon atoms with hydrogen atoms attached to them. Using your knowledge of intermolecular forces, why wouldn’t it be better to use a compound like glycerol. The formula of glycerol is CH$_2$OH(CH$_2$OH)$_2$.

the hydrogen bonding would keep the molecules together, making it more difficult to evaporate them into the gas phase.
Lay-Lussac’s Law Worksheet

Determine the pressure change when a constant volume of gas at 1.00 atm is heated from 20.0 °C to 30.0 °C.

\[
\begin{align*}
V_1 &= 1 \\
P_1 &= 1.00 \\
T_1 &= 293 K \\
V_2 &= x \\
P_2 &= x \\
T_2 &= 303 K \\
p_2 &= \frac{P_2}{T_2} \\
 &= \frac{x}{303} \\
(1.00) &= \frac{x}{293} \\
1.03 &= x \text{ atm}
\end{align*}
\]

2. A container of gas is initially at 0.500 atm and 25 °C. What will the pressure be at 125 °C?

\[
\begin{align*}
V_1 &= 1 \\
P_1 &= 0.500 \text{ atm} \\
T_1 &= 298 K \\
V_2 &= x \\
P_2 &= x \\
T_2 &= 423 K \\
\frac{(0.500 \text{ atm})}{298 K} &= \frac{x}{423 K} \\
x &= 0.710 \text{ atm}
\end{align*}
\]

3. A gas container is initially at 47 mm Hg and 77 K (liquid nitrogen temperature.) What will the pressure be when the container warms up to room temperature of 25 °C?

\[
\begin{align*}
V_1 &= 1 \\
P_1 &= 47 \text{ mm Hg} \\
T_1 &= 298 K \\
V_2 &= x \\
P_2 &= x \\
T_2 &= 273 K \\
\frac{47 \text{ mm Hg}}{77 K} &= \frac{x}{298 K} \\
x &= 180 \text{ mm Hg}
\end{align*}
\]

4. A gas thermometer measures temperature by measuring the pressure of a gas inside the fixed volume container. A thermometer reads a pressure of 248 kPa at 0 °C. What is the temperature when the thermometer reads a pressure of 345 kPa?

\[
\begin{align*}
V_1 &= 1 \\
P_1 &= 248 \text{ kPa} \\
T_1 &= 273 K \\
P_2 &= x \text{ kPa} \\
T_2 &= x \text{ K} \\
\frac{248}{273} &= \frac{345}{x} \\
x &\approx 380 \text{ K}
\end{align*}
\]
Ideal Gas Law Stoichiometry Worksheet

1) For the reaction $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O(}\text{g})$, how many liters of water can be made from 5 L of oxygen gas and an excess of hydrogen at STP?

$$\frac{5\text{L O}_2}{1\text{ mol O}_2} \times \frac{2\text{ mol H}_2\text{O}}{22.4 \text{ L H}_2\text{O}} = 10 \text{ L H}_2\text{O}$$

2) How many liters of water can be made from 55 grams of oxygen gas and an excess of hydrogen at STP?

$$\frac{55\text{ g O}_2}{32\text{ g O}_2} \times \frac{1\text{ mol O}_2}{32\text{ g O}_2} \times \frac{2\text{ mol H}_2\text{O}}{22.4 \text{ L H}_2\text{O}} = 77 \text{ L H}_2\text{O}$$

3) How many liters of water can be made from 55 grams of oxygen gas and an excess of hydrogen at a pressure of 12.4 atm and a temperature of 85° C?

$$PV = nRT$$

$$\frac{55\text{ g O}_2}{32\text{ g O}_2} \times \frac{1\text{ mol O}_2}{32\text{ g O}_2} \times \frac{2\text{ mol H}_2\text{O}}{22.4 \text{ L H}_2\text{O}} = 1.719$$

4) How many liters of water can be made from 34 grams of oxygen gas and an excess amount of hydrogen gas at STP?

$$\frac{34\text{ g O}_2}{32\text{ g O}_2} \times \frac{1\text{ mol O}_2}{32\text{ g O}_2} \times \frac{2\text{ mol H}_2\text{O}}{22.4 \text{ L H}_2\text{O}} = 48 \text{ L H}_2\text{O}$$

5) $\frac{2}{2} \text{Na(s)} + \frac{2}{2} \text{Cl}_2(\text{g}) = \frac{2}{2} \text{NaCl(s)}$

a. Balance the above reaction.

b. What volume of chlorine gas, measured at STP, is necessary for the complete reaction of 4.81 g of sodium metal.

$$\frac{4.81\text{ g Na}}{23.49\text{ g Na}} \times \frac{1\text{ mol Na}}{1\text{ mol Cl}_2} \times \frac{22.4 \text{ L Cl}_2}{1\text{ mol Cl}_2} = 2.34 \text{ L Cl}_2$$

Answers: 1) 10.0 L H$_2$O  
2) 77.0 L H$_2$O  
3) 8.15 L H$_2$O  
4) 35.0 L H$_2$O  
5) a) 2, 1, 2 b) 2.34 L CO$_2$
6) \( C_3H_8(g) + \frac{5}{2} O_2(g) \rightarrow 3 CO_2(g) + 4 H_2O(g) \)

a. Balance the above reaction.

b. What volume of oxygen gas at 25\(^\circ\)C and 1.04 atm is needed for the complete combustion of 5.53 g of propane?

\[
PV = nRT \\
(1.04 \text{ atm})(x) = \left(0.125 \text{ mol}\right)(0.0821)(298) \\
x = 2.94 \text{ L C}_3\text{H}_8 \div 1 \text{ mol C}_3\text{H}_8 \times 5 \text{ mol O}_2 \div 22.4 \text{ L C}_3\text{H}_8 = 0.125 \text{ mol O}_2
\]

7) \( \frac{2}{2} \text{K}_2\text{MnO}_4(aq) + 5 \text{Cl}_2(g) \rightarrow 2 \text{KMnO}_4(aq) + 2 \text{KCl}(aq) \)

a. Balance the above reaction.

b. What volume of \( \text{Cl}_2(g) \), measured at STP, is needed to produce 10.0 g of \( \text{K}_2\text{MnO}_4 \)?

\[
\frac{10.0 \text{ g K}_2\text{MnO}_4}{178.04 \text{ g K}_2\text{MnO}_4} = \frac{1 \text{ mol K}_2\text{MnO}_4}{2 \text{ mol Cl}_2} = \frac{22.4 \text{ L Cl}_2}{1 \text{ mol Cl}_2} = 0.709 \text{ L Cl}_2
\]

8) \( \frac{3}{2} \text{Mg}_3\text{N}_2(s) + \frac{3}{2} \text{H}_2\text{O}(l) \rightarrow 3 \text{MgO}(s) + 2 \text{NH}_3(g) \)

a. Balance the above reaction.

b. If 10.3 g of magnesium nitride is treated with 10.3 g of water, what volume of ammonia gas would be collected at 24\(^\circ\)C and 0.989 atm?

\[
\frac{10.3 \text{ g Mg}_3\text{N}_2}{100.95 \text{ g Mg}_3\text{N}_2} \times \frac{2 \text{ mol NH}_3}{1 \text{ mol Mg}_3\text{N}_2} = \frac{1 \text{ mol NH}_3}{1 \text{ mol NH}_3} = 6.49 \text{ L}
\]

9) \( \frac{2}{2} \text{Cl}_2(g) + \frac{3}{2} \text{C}_2\text{H}_2(g) \rightarrow \frac{3}{2} \text{C}_2\text{H}_2\text{Cl}_4(l) \)

a. Balance the above reaction.

b. What volume of \( \text{Cl}_2 \) will be needed to make 75.0 grams of \( \text{C}_2\text{H}_2\text{Cl}_4 \) at 24.0\(^\circ\)C and 767 mm Hg?

\[
PV = nRT \\
(767 \text{ mm Hg})(773 \text{ mm Hg})(x) = (0.447 \text{ mol})(624)(297) \\
x = 10.7 \text{ L C}_2\text{H}_2\text{Cl}_4 \div 1 \text{ mol C}_2\text{H}_2\text{Cl}_4 \times 2 \text{ mol Cl}_2 \div 22.4 \text{ L C}_2\text{H}_2\text{Cl}_4 = 6.447 \text{ mol}
\]

10) \( \frac{2}{5} \text{C}_2\text{H}_6(g) + 5 \text{O}_2(g) \rightarrow 2 \text{CO}_2(g) + \frac{18}{2} \text{H}_2\text{O}(g) \)

a. Balance the above reaction.

b. How many grams of water would be produced if 20.0 liters of \( \text{O}_2 \) gas were burned at a temperature of -10.0\(^\circ\)C and a pressure of 1.3 atm?

\[
PV = nRT \\
(1.3 \text{ atm})(200 \text{ L O}_2) = x (0.0821)(273) \\
x = 1.264 \text{ mol O}_2 \times 1 \text{ mol H}_2\text{O} \div 18 \text{ mol O}_2 = 0.089 \text{ mol H}_2\text{O}
\]

Answers:
6) a) 1, 5, 3, 4 b) 14.8 L O\(_2\) 7) a) 2, 1, 2, 2 b) 0.709 L Cl\(_2\) 8) a) 1, 3, 3, 2 b) 5.03 L NH\(_3\)
9) a) 2, 1, 1 b) 21.4 L Cl\(_2\) 10) a) 2, 25, 16, 18 b) 16g H\(_2\)O
How many moles of gas occupy 98 L at a pressure of 2.8 atmospheres and a temperature of 292°K?

a) What law is this? Ideal gas law
b) Solve the problem

\[ \frac{11 \text{ moles}}{} \]

2) If 5.0 g of O₂ are placed in a 30.0 L tank at a temperature of 25°C, what will the pressure be?

a) What law is this? Ideal
b) Solve the problem

\[ \frac{0.13 \text{ atm} = 13 \text{ kPa} = 99 \text{ torr}}{1} \]

3) A balloon is filled with 35.0 L of helium in the morning when the temperature is 20.0°C. By noon the temperature has risen to 45.0°C. What is the new volume of the balloon?

a) What law is this? Charles
b) What is the relationship? Direct
c) Predict whether the variable asked for will increase or decrease. Increase
d) Solve the problem

\[ \frac{38.0 \text{ L}}{1} \]

4) A 35 L tank of oxygen is at 315 K with an internal pressure of 190 atmospheres. How many moles of gas does the tank contain?

a) What law is this? Ideal \( PV = nRT \)
b) Solve the problem

\[ \frac{(190 \text{ atm})(35 \text{ L}) = n (0.0821)(315 \text{ K})}{n = 240 \text{ mol}} \]

5) A balloon that can hold 85 L of air is inflated with 3.5 moles of gas at a pressure of 1.0 atmosphere. What is the temperature in °C of the balloon?

a) What law is this? Ideal \( PV = nRT \)
b) Solve the problem

\[ \frac{(1.0 \text{ atm})(85 \text{ L}) = (3.5 \text{ moles})(0.0821)(x)}{x = \frac{8910 \text{ K} - 273}{23^\circ \text{C}}} \]

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6) CaCO₃ decomposes at 1200°C to form CO₂ gas and CaO. If 25 L of CO₂ are collected at 1200°C, what will the volume of this gas be after it cools to 25°C?
   a) What law is this? \[ \frac{V_1}{T_1} = \frac{V_2}{T_2} \] direct
   b) What is the relationship?
   c) Predict whether the variable asked for will increase or decrease.
   d) Solve the problem
   \[ \frac{25 \text{ L}}{1473 \text{ K}} = \frac{x}{298 \text{ K}} \]
   \[ x = 5.01 \text{ L} \]

7) A helium balloon with an internal pressure of 1.00 atm and a volume of 4.50 L at 20.0°C is released. What volume will the balloon occupy at an altitude where the pressure is 0.600 atm and the temperature is −20.0°C?
   a) What law is this? \text{ combination}
   b) Solve the problem
   \[ 6.48 \text{ L} \]

8) There are 135 L of gas in a container at a temperature of 260°C. If the gas was cooled until the volume decreased to 75 L, what would the temperature of the gas be?
   a) What law is this? \[ \frac{V_1}{T_1} = \frac{V_2}{T_2} \] direct
   b) What is the relationship?
   c) Predict whether the variable asked for will increase or decrease.
   d) Solve the problem
   \[ \frac{135 \text{ L}}{533 \text{ K}} = \frac{75 \text{ L}}{x} \]
   \[ x = 296 \text{ K} \]

9) A 75 L container holds 62 moles of gas at a temperature of 215°C. What is the pressure in atmospheres inside the container?
   a) What law is this? \text{ Ideal}
   b) Solve the problem
   \[ 33 \text{ atm} \]
11) A gas canister can tolerate internal pressures up to 210 atmospheres. If a 2.0 L canister holding 3.5 moles of gas is heated to 1350°C, will the canister explode?

a) What law is this? Ideal

b) Solve the problem

\[(x)(2.0\text{ L}) = (3.5\text{ mol})(0.0821)(1623\text{ K})\]

\[x = 233\text{ L} \text{ yes will explode}\]

12) Put the following gases in order of increasing rate of diffusion: H₂, F₂, Cl₂, CO₂, CO

a) What law is this? Dalton

b) What is the relationship?

c) Solve the problem

\[\text{H₂, CO, CO₂, F₂, Cl₂}\]

13. An unknown gas effuses 1.35 times faster than NO, what is the molar mass of the gas?

a) What law is this? Graham's

b) What is the relationship? The lower the mass, the faster the rate

c) Predict whether the variable asked for will increase or decrease.

d) Solve the problem

\[1.35 = \sqrt{\frac{30.01}{\sqrt{x}}}\]

\[16.5\text{ g/mol}\]

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