The Fluid States

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Printed: October 23, 2014

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CHAPTER 1 The Fluid States

CHAPTER OUTLINE

In the photo above, we see the water line of a large cargo ship. For this cargo ship, as for any object submerged or partially submerged in water, the upward force of the water that is displaced by the ship, called buoyancy, is exactly equal to the weight of the displaced ship. This cargo ship is unloaded, which means that the ship sinks into the water about 13 feet and that the water displaced by the volume of the ship underwater will have a weight equal to the weight of the empty ship. As cargo, and therefore weight, is added to the ship, it will submerge further. This ship can submerge another 9 feet as it is loaded with cargo. As it submerges, it displaces more water so that the buoyant force can support more weight. In this chapter, you will learn about the forces involved in fluids, in addition to fluid expansion and the laws governing the behavior of gases.

1.1 Pressure in Fluids

- Define pressure.
- Calculate the pressure below the surface of liquids using the formula $P = \rho g h$.

This is the Russian ocean submersible "Mir." Submersibles like this are necessary for research or work at great depths in the ocean because of the massive pressure. This craft can operate as deep as 6000 meters below the surface. The pressure at 6000 meters below the ocean surface exceeds 8500 pounds per square inch.

Pressure in Fluids

Pressure is defined as force per unit area, where the force F is understood to be acting perpendicular to the surface area, A.

$$Pressure = P = \frac{F}{A}$$

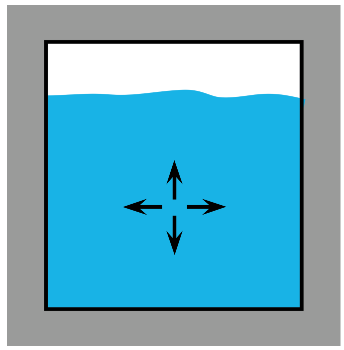
The SI unit for pressure is N/m^2. This unit is also known as a **pascal** (Pa): 1 Pa = 1 N/m^2.

Example: Consider a 80.0 kg person whose two feet cover an area of 500. cm^2. Determine the pressure applied to the ground by his feet.

Solution: The force exerted by this person on the ground would be (80.0 kg)(9.80 m/s^2) = 784 N. The area over which this force is exerted would be 0.0500 m^2.

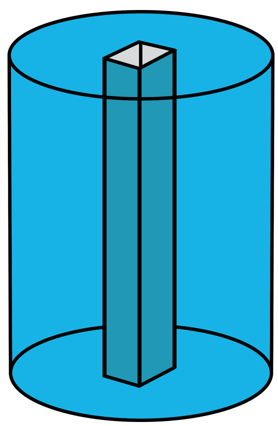
$$P = \frac{F}{A} = \frac{784 \text{ N}}{0.0500 \text{ m}^2} = 15,700 \text{ Pa}$$

It has been determined experimentally that a **fluid** exerts pressure equally in all directions. In the sketch below, from any given point below the surface of the fluid, the pressure in all directions is the same. The fluid exerts the same pressure upward from this point as it does downward.



We can calculate how the pressure of a fluid varies with depth, assuming the fluid has uniform density.

Consider a gigantic tub filled with water as shown below. A column of water with a cross-sectional area of 1.00 m^2 is designated. If we multiply the cross-sectional area by the height of the column, we get the volume of water in this column. We can then multiply this volume by the density of water, 1000. kg/m^3, and get the mass of water in the column. We then multiply this mass by the acceleration due to gravity, g, to get the weight of the water in this column.



$$F_{\text{weight}} = (\text{area})(\text{height})(\rho)(g)$$

The pressure exerted by this force would be exerted over the area at the bottom of the column.

$$P = \frac{F}{A} = \frac{\rho g h A}{A} = \rho g h$$

Therefore, the pressure of a column of fluid is proportional to the density of the fluid and to the height of the column of fluid above the level. This is the pressure due to the fluid itself. If an external pressure is exerted at the surface, this must also be taken into account.

Example Problem: The surface of the water in a storage tank is 30.0 m above a water faucet in the kitchen of a house. Calculate the water pressure at the faucet.

Solution: The pressure of the atmosphere acts equally at the surface of the water in the storage tank and on the water leaving the faucet –so it will have no effect. The pressure caused by the column of water will be:

$P = \rho gh = (1000.\ kg/m^3)(9.80\ m/s^2)(30.0\ m) = 294,000\ Pa$

The pressure of the earth's atmosphere, as with any fluid, increases with the height of the column of air. In the case of earth's atmosphere, there are some complications. The density of the air is not uniform but decreases with altitude. Additionally there is no distinct top surface from which height can be measured. We can, however, calculate the approximate difference in pressure between two altitudes using the equation $P = \rho g\Delta h$. The average pressure of the atmosphere at sea level is 1.013×10^5 Pa. This pressure is often expressed as 101.3 kPa.

Summary

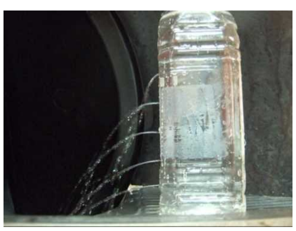
- Pressure is defined as force per unit area, $P = \frac{F}{A}$.
- The SI unit for pressure is N/m^2 which has been named *pascal* (Pa).
- It has been determined experimentally that a fluid exerts pressure equally in all directions.
- The pressure of a column of fluid is proportional to the density of the fluid and to the height of the column of fluid above the level, $P = \rho gh$.
- The average pressure of the atmosphere at sea level is 1.013×10^5 Pa, or 101.3 kPa.

Practice

Questions

The following video explains fluid pressure. Use this resource to answer the three questions that follow.

http://www.youtube.com/embed/oUK7agBG4KA



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Click image to the left for use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/81404

1. Why do the streams of water at the bottom of the bottle go the farthest?
2. Why does water stop flowing out of the top hole even before the water level falls below it?

Additional Practice Problems:

Questions

1. Calculate the pressure produced by a force of 800. N acting on an area of $2.00\ m^2$.
2. A swimming pool of width 9.0 m and length 24.0 m is filled with water to a depth of 3.0 m. Calculate pressure on the bottom of the pool due to the water.
3. What is the pressure on the side wall of the pool at the junction with the bottom of the pool in the previous problem?

Review

Questions

1. If you push the head of a nail against your skin and then push the point of the same nail against your skin with the same force, the point of the nail may pierce your skin while the head of the nail will not. Considering that the forces are the same, what causes the difference?
2. A brick of gold is 10.0 cm wide, 10.0 cm high, and 20.0 cm long. The density of gold is 19.3 g/cm^3.
   (a) What pressure does the brick exert on the table if the brick is resting on its side?
   (b) What pressure does the brick exert on the table if it is resting on its end?
3. What is the total force and the pressure on the bottom of a swimming pool 8.0 m by 15.0 m whose uniform depth is 2.0 m?

- **fluid:** A continuous, amorphous substance whose molecules move freely past one another and that has the tendency to assume the shape of its container; a liquid or gas.
- **pressure:** Pressure is force per unit area.
- **pascal:** The pascal (symbol: Pa) is the SI derived unit of pressure, named after the French mathematician, physicist, inventor, writer, and philosopher Blaise Pascal. It is a measure of force per unit area, defined as one newton per square meter.

1.2 Pascal's Principle

- State Pascal's Principle.
- Use Pascal's Principle to make calculations on hydraulic systems.

A person is able to lift the entire rear end of the automobile using only one hand with the hydraulic jack shown in the image. Hydraulic systems are similar to simple machines in that they can produce very large mechanical advantages.

Pascal's Principle

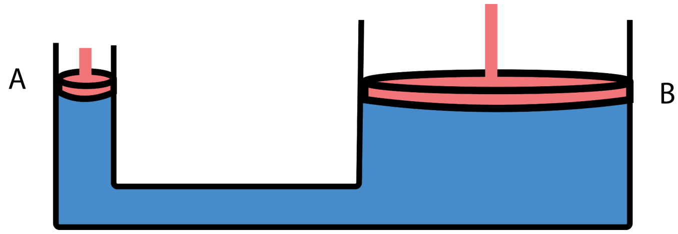
The earth's atmosphere exerts a pressure on all objects with which it is in contact. Atmospheric pressure acting on a fluid is transmitted throughout that fluid. For example, the water pressure at 100. m below the surface of a lake is 9.8×10^5 Pa. The total pressure at that point, however, is the pressure of the water plus the pressure of the air above the water. The pressure of the air at the surface of the water is 1.0×10^5 Pa, or 1 atm (atmosphere). Therefore, the total pressure at 100. m below the surface of the water is 9.8×10^5 Pa + 1.0×10^5 Pa = 10.8×10^5 Pa.

This is an example of **Pascal's Principle**, which states that pressure applied to a confined liquid increases the pressure throughout by the same amount. A number of practical devices take advantage of this principle. Hydraulic brakes, **hydraulic lifts**, and hydraulic presses are three useful tools that make use of Pascal's Principle.

The sketch below is an example of a hydraulic lift. We have a confined liquid in contact with two pistons (A and B) of different sizes. The pressure of the liquid on these two pistons is the same (Pascal's principle). Therefore, $F_A = F_B$,

and $\frac{F_A}{A_A} = \frac{F_B}{A_B}$ *and* $\frac{F_A}{F_B} = \frac{A_A}{A_B}$.

Suppose that the area of piston A is 4.0 cm^2 and the area of piston B is 200. cm^2. If we place an automobile weighing 10,000 N on piston B, we can lift that car by exerting a force of 200 N on piston A. This is another form of simple machine and its ideal mechanical advantage is 50. The ideal mechanical advantage of a hydraulic lift equals the ratio of the large piston area to the small piston area.



Summary

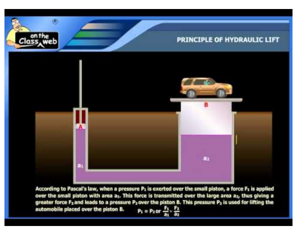
- Atmospheric pressure acting on a fluid is transmitted throughout that fluid.
- Pascal's Principle states that pressure applied to a confined liquid increases the pressure throughout by the same amount.

Practice

Questions

The following video is a lecture on the hydraulic lift. Use this resource to answer the questions that follow.

http://youtu.be/A3ormYVZMXE



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Click image to the left for use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/64117

1. What property of liquids allows for the great mechanical advantage of a hydraulic lift?
2. If the ratio of A2 to A1 was 100, what force would be required to lift a 10000 N car?

Practice problems for hydraulic lifts:

http://w3.shorecrest.org/~Lisa_Peck/Physics/syllabus/phases/liquids/hydraulic_ws.pdf

Review

Questions

1. In a hydraulic lift whose input line has a cross-sectional area of 1.00 cm^2 and whose output line has a cross-sectional area of 20.0 cm^2, what is the largest mass (kg) that can be lifted by an input force of 1000. N?
2. In a hydraulic lift whose IMA is 50, how far (ideally) will the output platform be lifted when the input platform is depressed 100. cm?
3. A 20.0 N force is exerted on the small piston of a hydraulic system. The cross-sectional area of the small piston is 0.0500 m^2. What is the magnitude of the weight than can be lifted by the large piston, which has a cross-sectional area of 0.100 m^2?

- **Pascal's principle:** Pressure applied to an enclosed fluid is transmitted undiminished to every part of the fluid, as well as to the walls of the container.
- **hydraulic lift:** A type of machine that uses a hydraulic apparatus to lift or move objects using the force created when pressure is exerted on liquid in a piston.

1.3 Archimedes' Principle and Buoyancy

- State Archimedes' Principle.
- Describe buoyancy.
- Make calculations of buoyancy.
- Make calculations of floating objects' displacement.

This cargo ship displaces an amount of water such that the weight of the displaced water is exactly equal to the weight of the ship and its cargo. The displacement of water is what produces the buoyancy to float this ship. When this photo was taken, the ship was empty so it did not sink very deep in the water to displace the necessary weight. When this ship is fully loaded with cargo, the water line will be where the black paint meets the red paint.

Archimedes' Principle and Buoyancy

If an object is submerged in a liquid, the object displaces a volume of the liquid equal to the volume of the submerged object. Legend has it that this observation was made by Archimedes when he sat in a bath tub that was filled to the top of the tub. The volume of water that overflowed was equal to his own volume. The forces exerted by the fluid on the sides of the submerged object are balanced. However, the forces exerted by the fluid on the top and bottom of the object are not equal. The force exerted by the liquid below the object is greater than the force exerted by the liquid above it; the liquid exerts a net upward force on the submerged or floating object. This force is called **buoyancy**, and its magnitude is equal to the weight of the displaced water. **Archimedes' Principle** states that the buoyant force is equal to the weight of the displaced liquid.

Example Problem: The density of steel is 9000. kg/m^3 and the density of water is 1000. kg/m^3. If a cube of steel that is 0.100 m on each side is placed in a tank of water and weighed while under water, what is the apparent weight of the cube?

Solution: The volume of the cube is 0.00100 m^3.

The mass of the cube is 9.00 kg.

The weight of the cube when not submerged in water = (9.00 kg)(9.80 m/s^2) = 88.2 N

The mass of water displaced by the cube = 1.00 kg

The weight of the water displaced by the cube = 9.80 N

The buoyant force on the steel cube = 9.80 N

Apparent weight of cube under water = 88.2 N - 9.80 N = 78.4 N

Example Problem: A hollow metal cube 1.00 m on each side has a mass of 600. kg. How deep will this cube sink when placed in a vat of water?

Solution: Since the weight of the cube is 5880 N, it will need to displace 5880 N of water in order to float.

Volume of submerged portion of cube $= (1.00 \text{ m})(1.00 \text{ m})(x \text{ m}) = x \text{ m}^3$

Mass of water displaced $= 1000x$ kg

Weight of water displaced $= 9800x$ N

$9800x = 5880$

$x = 0.600$ m

The cube will sink such that 0.60 m are underwater and 0.40 m are above water.

Summary

- If an object is submerged in a liquid, the object will displace a volume of the liquid equal to the volume of the submerged object.
- The forces exerted by the fluid on the sides of the submerged object are balanced, but the forces exerted by the fluid on the top and bottom of the object are not equal.
- The liquid exerts a net upward force on the submerged or floating object, called buoyancy.
- The magnitude of buoyancy is equal to the weight of the displaced water.
- Archimedes' Principle states that the buoyant force is equal to the weight of the displaced liquid.

Practice

Questions

The following video is on buoyancy. Use this resource to answer the two questions that follow.

http://dsc.discovery.com/tv-shows/mythbusters/videos/lets-talk-buoyancy.htm

Multimedia

MEDIA

Click image to the left for use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/82772

1. Why were they unable to use the overturned boat as a submarine?
2. Why does the bubble in the tube shrink as it is taken lower in the pool?

Additional Practice Questions:

1. If a ship has a mass of 200,000,000 kg, how much water would it need to displace in order to float?
2. A 40.0 kg cylinder that is 1.2 m tall and has a 0.20 m diameter falls off the pier and gets completely submerged when it hits the water. What is the buoyant force on the cylinder when it is under water? Will it sink or float? The formula for finding the volume of a cylinder is $\pi r^2 h$.
3. The formula for the volume of a sphere is $4\pi r^3$. A 1.7×10^{-6} kg air bubble has a diameter of 1.00 cm and is submerged in water. What is the buoyant force on the bubble?

Review

Questions

1. A cylinder with a radius of 11 cm and a height of 3.4 cm has a mass of 10.0 kg.
   (a) What is the weight of this cylinder?
   (b) What is the weight of this cylinder when it is submerged in water?
2. A wooden raft is 2.00 m wide, 3.00 m long, and 0.200 m deep. The raft and its occupants have a mass of 700. kg. How deep will the raft sink below the water when floating?
3. For the raft in problem #2, how many 50. kg people can be added to the raft before it sinks completely under water?
4. The density of gold is 19,320 kg/m^3 and the density of mercury is 13,500 kg/m^3. If a cube of gold that is 0.100 m on each side is placed in a tank of mercury and weighed while under the surface, what is the apparent weight of the cube?

- **buoyancy:** The buoyant force is the upward force exerted by any fluid upon a body placed in it.
- **Archimedes' Principle:** States that a body immersed in a fluid is buoyed up by a force equal to the weight of the displaced fluid.

1.4 Combined Gas Law

- Understand Boyle's, Charles', and Gay-Lussac's Laws.
- State the Combined Gas Law.
- Given five of the six unknowns in the combined gas law, solve for the sixth.

In order to design hot air balloons like these, engineers must make gas law calculations, buoyancy calculations, and have knowledge of the density of air at different altitudes.

Combined Gas Law

For a given quantity of gas, it has been found experimentally that the volume of the gas is inversely proportional to the pressure applied to the gas when the temperature is kept constant. That is,

$$V \propto \frac{1}{P} \text{ at a constant } T.$$

For example, if the pressure on a gas is doubled, the volume is reduced to half its original volume. This relationship is known as **Boyle's Law**. Boyle's Law can also be written $PV =$ constant at constant T. As long as the temperature and the amount of gas remains constant, any variation in the pressure or volume will result in a change in the other one, keeping the product at a constant value.

Pressures are given in a multitude of units. We've already discussed Pascals, and we know that another unit for pressure is the atmosphere (1 atm = 101.3 x 10^5 Pa). The third commonly used pressure unit is the torr (symbol: Torr). 760 torr is 1 atm, but 1 torr is also the increase in pressure necessary to cause liquid mercury to rise by 1 mm.

For that reason, torr is also commonly referred to as "millimeters mercury." Another pressure unit commonly used in our everyday world is psi, or pounds per square inch, though neither psi nor torr are SI units.

Temperature also affects the volume of a gas. Jacques Charles found that when the pressure is held constant, the volume of a gas increases in direct proportion to its absolute temperature. This relationship became known as **Charles' Law**.

$$V \propto T \text{ at constant } P.$$

A third gas law, known as **Gay-Lussac's Law**, states that at constant volume, the pressure of a gas is directly proportional to the absolute temperature.

$$P \propto T \text{ at constant } V.$$

The kinetic-molecular theory assumes that there are no attractive forces between the molecules and that the volume of the molecules themselves is negligible compared to the volume of the gas. At high temperatures and low pressures, these assumptions are true and the gases follow the **gas laws** very accurately. However, these three laws are true only as long as the pressure and density are relatively low. When a gas is compressed to the point that the molecular volume is a significant portion of the gas volume, the gas laws begin to fail. Similarly, when gases become so dense that the molecules begin to attract each other, the gas laws also fail. These changes are expressed in the Van der Waals equations.

These three gas laws can be combined into the **Combined Gas Law** as follows:

$$PV \propto T \ or \ \frac{PV}{T} = \text{constant}$$

A commonly used form of the combined gas law states that, for a sample of gas, the ratio of the product of the original pressure and volume to the original temperature will equal the ratio of the product of a new pressure and volume to the new temperature, or

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

This equation is useful when operating with the same sample of gas, and given five of the variables, to solve for the sixth.

When solving problems with temperature in them, the calculations require that temperatures be in Kelvin. Be careful to convert to Kelvin when given temperatures in Celsius.

Example Problem: A sample of gas has a volume of 2.00 L and a pressure of 0.750 kPa when its temperature is 25°C. If the volume is expanded to 4.00 L and the pressure reduced to 0.500 kPa, what must the temperature become?

Solution: The relationships between volume and temperature and pressure and temperature expressed in the gas laws are only true when the kinetic energy of the molecules are directly proportional to the temperature. Therefore, when dealing with all gas laws, the temperatures must be expressed in Kelvin.

Given:

$$\begin{array}{ll} P_1 = 0.750\ kPa & P_2 = 0.500\ kPa \\ V_1 = 2.00\ L & V_2 = 4.00\ L \\ T_1 = 298\ K & T_2 = ? \end{array}$$

$$T_2 = \frac{P_2 V_2 T_1}{P_1 V_1} = \frac{(0.500\ kPa)(4.00\ L)(298\ K)}{(0.750\ kPa)(2.00\ L)} = 397\ K$$

Summary

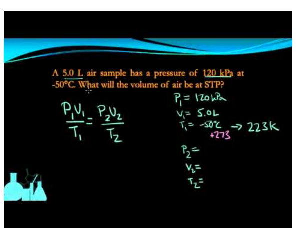
- For a given quantity of gas, it has been found experimentally that the volume of the gas is inversely proportional to the pressure applied to the gas when the temperature is kept constant.
- Boyle's Law is $V \propto \frac{1}{P}$ at constant T.
- Charles' Law is $V \propto T$ at constant P.
- Gay-Lussac's law states that at constant volume, the pressure of a gas is directly proportional to the absolute temperature, $P \propto T$ at constant V.
- These three gas laws can be combined into a so-called combined gas law, $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$.

Practice

Questions

The following video covers the combined gas law. Use this resource to answer the questions that follow.

http://youtu.be/_wxhSanQyIs



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URL: http://www.ck12.org/flx/render/embeddedobject/64119

1. What must be held constant for the combined gas law to be true?
2. What happens to the combined gas law if temperature, pressure, or volume are held constant?

Combined gas law problems with solutions:

http://www.sciencebugz.com/chemistry/chsolngaswkst.htm

Review

Questions

1. A sample of gas has a volume of 800. mL at -23.0°C and 300. Torr. What would the volume of the gas be at 227.0°C and 600. Torr?

2. 500.0 L of gas are prepared at 0.921 atm pressure and 200.0°C. The gas is placed into a tank under high pressure. When the tank cools to 20.0°C, the pressure is 30.0 atm. What is the volume of the gas under these conditions?
3. What is the volume of gas at 2.00 atm and 200.0 K if its original volume was 300. L at 0.250 atm and 400.0 K?

- **gas laws:** A series of laws in physics that predict the behavior of an ideal gas by describing the relations between the temperature, volume, and pressure. The laws include Boyle's law, Charles' law, and Gay-Lussac's law, and are combined in the combined gas law.

1.5 Universal Gas Law

- State the universal gas law.
- State the universal gas law constant, R.
- Given three of the four unknowns in the universal gas law, solve for the fourth.

Compressed gases provide vital fuels for industry and for homes and farms in rural areas.

Universal Gas Law

The combined gas law, $PV \propto T$, is true for a particular sample of gas. If any gas is added or allowed to leak out, however, the relationship is lost. In order to get a relationship that is true for any sample of gas, it is necessary to incorporate a term for the amount of gas. From observations as simple as blowing up a balloon, it is clear that increasing the amount of gas increases the volume.

Because different gases have different weights per molecule, including a term for mass of gas does not produce a consistent equation. If, however, we include a term expressing the number of moles of gas rather than its mass, we can produce a constant proportionality. A mole is a unit representing the number of atoms present. The letter n is used to represent the moles of substance. Incorporating n into the equation yields $PV \propto nT$. If we insert a letter, R, to represent the constant of proportionality, we get the normal form of the **universal gas law**, $PV = nRT$.

The unit term for n is always moles and T is always in Kelvin. The units for pressure and volume, however, may vary. The value of R depends on the units that are used for pressure and volume.

TABLE 1.1: Values of the Universal Gas Law Constant, R

Pressure Units	Volume Units	Units for n	Units for T	Value of R
atm	liters	moles	Kelvin	0.0821 L•atm/mol•K

TABLE 1.1: (continued)

atm	milliliters	moles	Kelvin	82.1 mL•atm/mol•K

Since the product of (liters)(atm) can be converted to joules, we also have a value for R where liters $\times$ atm have been converted to joules, $R = 8.314$ J/mol $\cdot$ K. The two common values of the **universal gas law** R**constant** are 0.0821 L $\cdot$ atm/mol $\cdot$ K and $R = 8.314$ J/mol $\cdot$ K.

Most universal gas law problems are calculated at STP. STP stands for *standard temperature and pressure,* which is the most commonly calculated temperature and pressure value. STP is defined as 1.00 atm and 0°C, or 273 K.

Example Problem: Determine the volume of 1.00 mol of any gas at STP.

Solution: First isolate V from PV=nRT. Then plug in known values and solve.

$$V = \frac{nRT}{P} = \frac{(1.00 \text{ mol})(0.0821 \text{ L} \cdot \text{atm/mol} \cdot \text{K})(273 \text{ K})}{(1.00 \text{ atm})} = 22.4 \text{ liters}$$

For any gas at STP, one mole has a volume of 22.4 liters. This can be an extremely convenient conversion factor.

Example Problem: A sample of oxygen gas occupies 10.0 liters at STP. How many moles of oxygen are in the container?

Solution:

$$n = \frac{PV}{RT} = \frac{(1.00 \text{ atm})(10.0 \text{ L})}{(0.0821 \text{ L} \cdot \text{atm/mol} \cdot \text{K})(273 \text{ K})} = 0.446 \text{ moles}$$

Summary

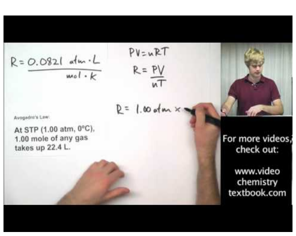
- The universal gas law is $PV = nRT$, where P is pressure, V is volume, n is number of moles, R is the universal gas law constant, and T is the absolute temperature.
- The value of R varies depending on the units used for P and V. Two common values are 0.0821 L $\cdot$ atm/mol $\cdot$ K and $R = 8.314$ J/mol $\cdot$ K.
- STP is standard temperature and pressure; 273 K and 1.00 atm.
- One mole of a gas at STP has a volume of 22.4 liters.

Practice

Questions

The following video discusses the constant R. Use this resource to answer the questions that follow.

http://youtu.be/kBgzzwCTddc



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1. Why is it important to have values for R in kPa, atm, and mmHg?
2. Why do the units of R include pressure, temperature, volume, and moles?

Instruction and practice problems involving the universal gas law:

http://www.sparknotes.com/testprep/books/sat2/chemistry/chapter5section10.rhtml

Review

Questions

1. The initial pressure in a helium gas cylinder is 30 atm. After many balloons have been blown up, the pressure in the cylinder has decreased to 6 atm while the volume and temperature remain the same. What fraction of the original amount of gas remains in the cylinder?
2. Calculate the volume of 8.88 mol of helium gas at 20.0°C and 1.19 atm pressure.

- **Universal gas law:** $PV = nRT$
- **Universal gas law constant:** Two common values are 0.0821 $L \cdot atm/mol \cdot K$ and $R = 8.314\ J/mol \cdot K$.

Fluid pressure equations apply to all fluids, including liquids and gases. Confined liquids are subject to the same pressure throughout, and gaseous fluids exert equal pressures on all sides of an object. As such, objects partially submerged in water are acted upon by a buoyant force, equal to the submerged weight. Finally, gases are subject to laws regarding the relationships between pressure, temperature, and volume; these laws are compiled into the Combined Gas Law and the Ideal Gas Law.

1.6 References

1. User:Wikisearcher/De.Wikipedia. http://commons.wikimedia.org/wiki/File:Draft_scale_at_the_ship_bow_%28PIC00110%29.jpg .
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