

The Mole

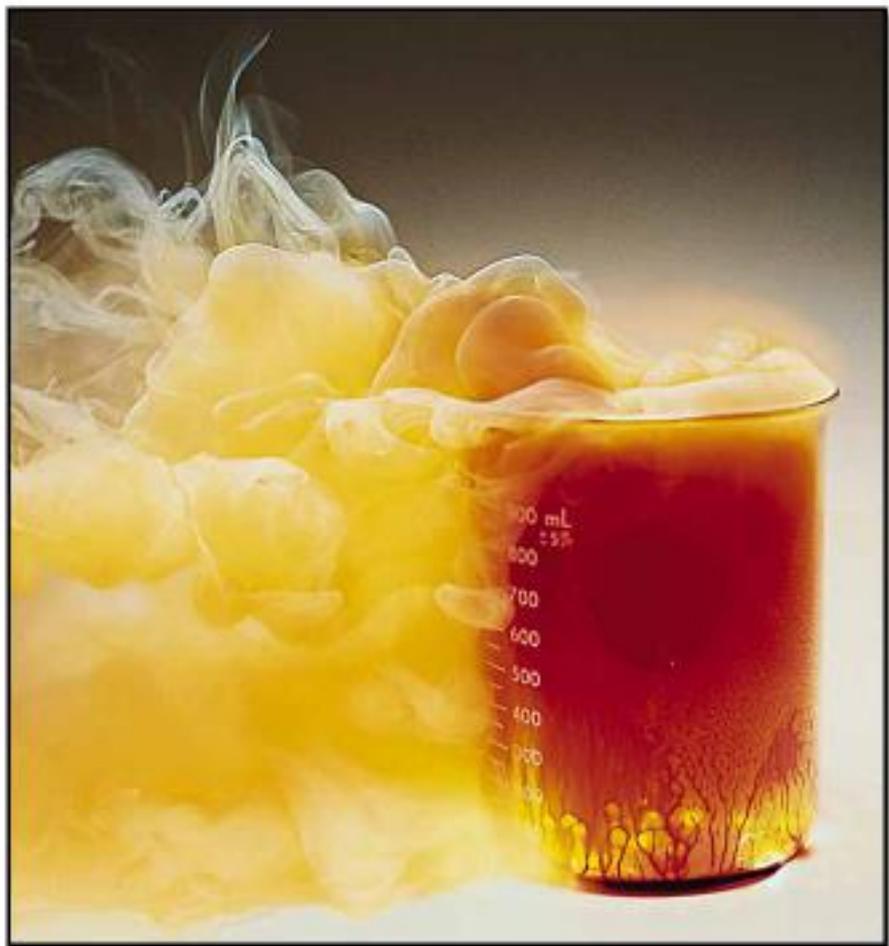


6.02×10^{23}



STOICHIOMETRY

- the study of the quantitative aspects of chemical reactions.

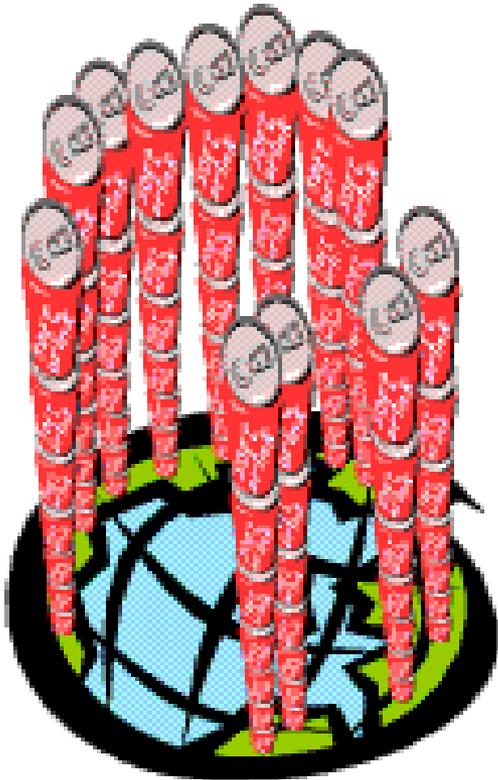


The Mole

- A counting unit
- Similar to a dozen, except instead of 12, it's 602 billion trillion
602,000,000,000,000,000,000,000
- 6.02×10^{23} (in scientific notation)
- This number is named in honor of **Amedeo Avogadro(1776 – 1856)**, who studied quantities of gases at a constant temperature and pressure and discovered that no matter what the gas was, there were the same number of molecules present. (Avogadro's Hypothesis)



Just How Big is a Mole?



- Enough soft drink cans to cover the surface of the earth to a depth of over 200 miles.
- If you had Avogadro's number of unpopped popcorn kernels, and spread them across the United States of America, the country would be covered in popcorn to a depth of over 9 miles.
- If we were able to count atoms at the rate of 10 million per second, it would take about 2 billion years to count the atoms in one mole.

Learning Check

Suppose we invented a new collection unit called a rapp. One rapp contains 8 objects.

1. How many paper clips in 1 rapp?

a) 1

b) 4

c) 8

2. How many oranges in 2.0 rapp?

a) 4

b) 8

c) 16

3. How many rapps contain 40 gummy bears?

a) 5

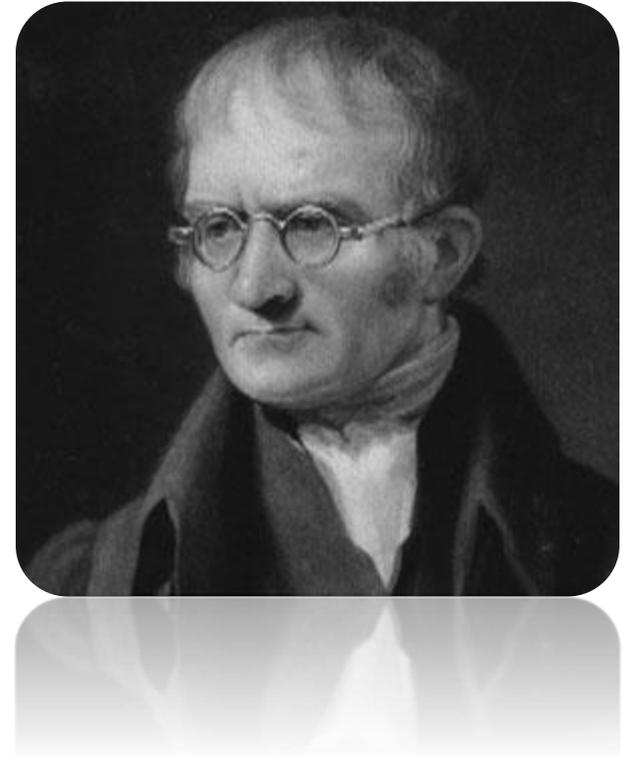
b) 10

c) 20

John Dalton 1766-1844

How much does an atom weigh?

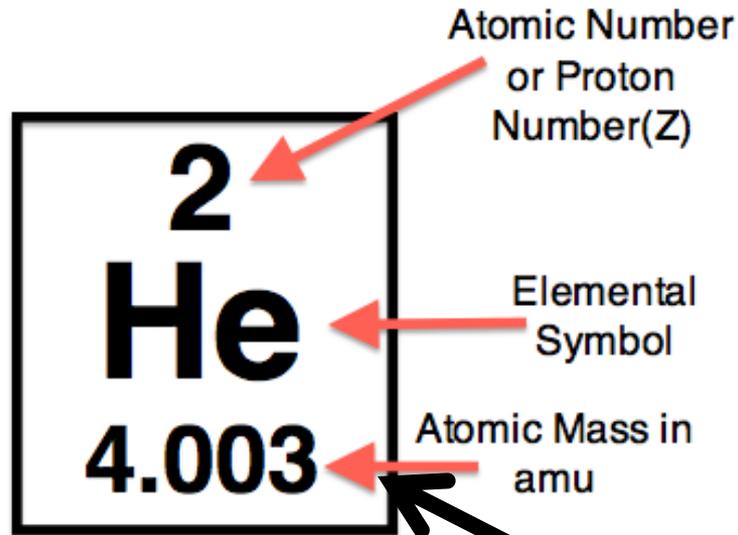
Dalton suggested that Hydrogen be assigned one atomic mass unit (amu) since it was the lightest of all the elements. The other elements were given amu's based on how many times heavier they were than hydrogen.



Carbon is 12 times heavier than hydrogen so it has an atomic mass of 12 amu.

Lead is 207 times heavier than hydrogen so it weighs 207 amu.

Wouldn't it be awesome if the periodic was measure in grams instead of amu's?

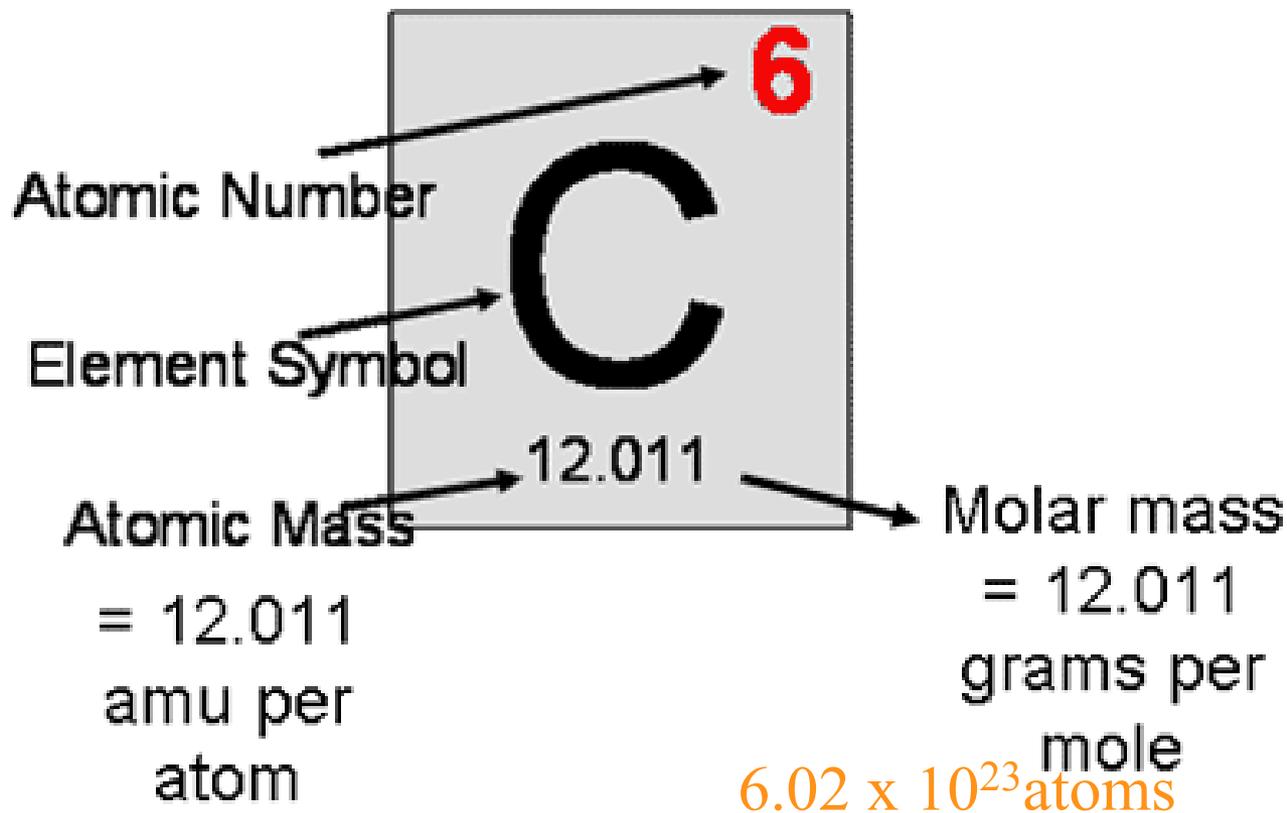


If this was grams life would be a lot easier.

Scientists calculated how many atoms were in 12 grams of carbon.

There are roughly 6.02×10^{23} atoms

They called this number Avogadro's number. Also called the **mole**.



Using the mole we don't have to change any numbers on the periodic table.

The Mole

- 1 dozen cookies = 12 cookies
- 1 mole of cookies = 6.02×10^{23} cookies

- 1 dozen cars = 12 cars
- 1 mole of cars = 6.02×10^{23} cars

- 1 dozen Al atoms = 12 Al atoms
- 1 mole of Al atoms = 6.02×10^{23} atoms

Note that the NUMBER is always the same, but the MASS is very different!

Mole is abbreviated mol (gee, that's a lot quicker to write, huh?)

A Mole of Particles

Contains 6.02×10^{23} particles

1 mole C = 6.02×10^{23} C atoms

1 mole H₂O = 6.02×10^{23} H₂O molecules

1 mole NaCl = 6.02×10^{23} NaCl “molecules”

(technically, ionics are compounds not molecules so they are called formula units)

6.02×10^{23} Na⁺ ions and

6.02×10^{23} Cl⁻ ions

Avogadro's Number as Conversion Factor

$$\frac{6.02 \times 10^{23} \text{ particles}}{1 \text{ mole}}$$

or

$$\frac{1 \text{ mole}}{6.02 \times 10^{23} \text{ particles}}$$

Note that a particle could be an atom OR a molecule!

Learning Check

1. Number of atoms in 0.500 mole of Al

$$0.500 \text{ mole of Al} \times \frac{6.02 \times 10^{23} \text{ atoms}}{\text{mole}} = 3.01 \times 10^{23} \text{ atoms}$$

2. Number of moles of S in 1.8×10^{24} S atoms

$$1.8 \times 10^{24} \text{ atoms} \times \frac{1 \text{ mole}}{6.02 \times 10^{23} \text{ atoms}} = 3.0 \text{ mole of S}$$

Molar Mass

- The Mass of 1 mole (in grams)
- Equal to the numerical value of the average atomic mass (get from periodic table)

1 mole of C atoms = 12.0 g

1 mole of Mg atoms = 24.3 g

1 mole of Cu atoms = 63.5 g

Other Names Related to Molar Mass

- **Molecular Mass/Molecular Weight:** If you have a single molecule, mass is measured in amu's instead of grams. But, the molecular mass/weight is the same numerical value as 1 mole of molecules. Only the units are different. (This is the beauty of Avogadro's Number!)
- **Formula Mass/Formula Weight:** Same goes for compounds. But again, the numerical value is the same. Only the units are different.
- **THE POINT:** You may hear all of these terms which mean the *SAME NUMBER*... just different units

Learning Check!

Find the molar mass

(usually we round to the tenths place)

A. 1 mole of Br atoms

B. 1 mole of Sn atoms

Molar Mass of Molecules and Compounds

Mass in grams of 1 mole equal numerically to the sum of the atomic masses

1 mole of CaCl_2

1 mole Ca x 40.1 g/mol = 40.1 g/mol

+ 2 moles Cl x 35.5 g/mol = 71.0 g/mol

= 111.1 g/mol CaCl_2

Learning Check!

A. **Molar Mass** of $\text{K}_2\text{O} = ?$ Grams/mole

B. **Molar Mass** of antacid $\text{Al}(\text{OH})_3 = ?$ Grams/mole

Learning Check

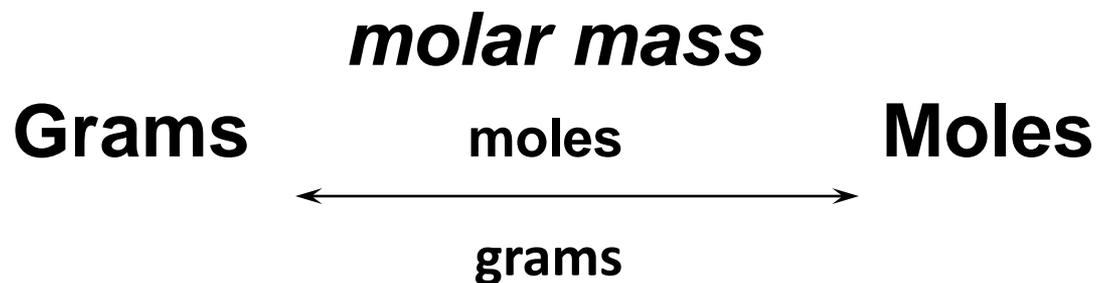
Prozac, $C_{17}H_{18}F_3NO$, is a widely used antidepressant that inhibits the uptake of serotonin by the brain. Find its molar mass.

Do
Molar Mass and
Formula Mass
Work sheet

YYYESS!



Calculations with Molar Mass



Converting Moles and Grams

Aluminum is often used for the structure of light-weight bicycle frames. How many grams of Al are in 3.00 moles of Al?

3.00 moles Al

? g Al



1. Molar mass of Al

1 mole Al = 27.0 g Al

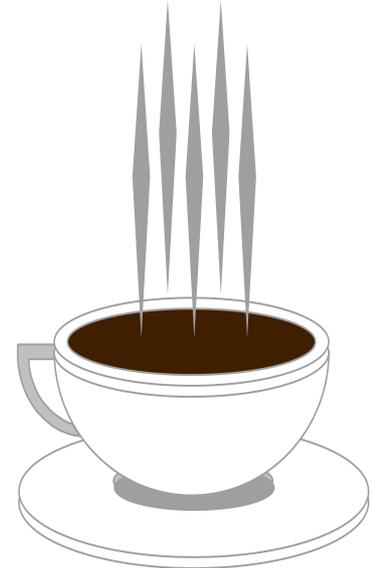
2. Conversion factors for Al

$$\frac{27.0\text{g Al}}{1 \text{ mol Al}} \quad \text{or} \quad \frac{1 \text{ mol Al}}{27.0 \text{ g Al}}$$

3. Setup **3.00 moles Al** **x** $\frac{27.0 \text{ g Al}}{1 \text{ mole Al}}$

Answer **= 81.0 g Al**

Learning Check!



The artificial sweetener aspartame (Nutra-Sweet) formula $C_{14}H_{18}N_2O_5$ is used to sweeten diet foods, coffee and soft drinks. How many moles of aspartame are present in 225 g of aspartame?

Calculations with Avogadro's number (6.02×10^{23})

$$\begin{array}{l} \text{\#Molecules} \\ \text{\#Atoms} \\ \text{\#Formula Units} \end{array} \times \frac{1 \text{ mole}}{6.02 \times 10^{23}} = \text{\# Moles}$$

$$\text{\# Moles} \times \frac{6.02 \times 10^{23}}{1 \text{ mole}} = \begin{array}{l} \text{\#Molecules} \\ \text{\#Atoms} \\ \text{\#Formula Units} \end{array}$$

Example

How many formula units are in 2.34 moles of NaCl.



Example

How many moles is 3.45×10^{26} molecules of oxygen?

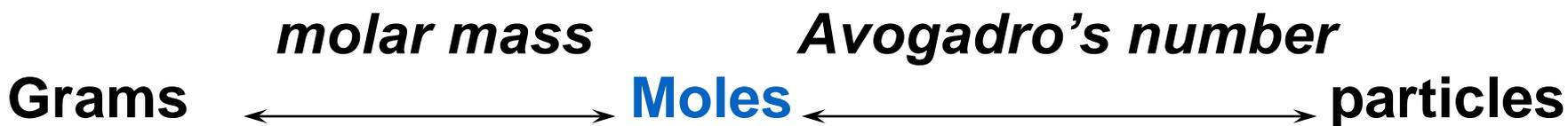
Do questions 1 to 15
of the
Moles, Molecules and
STP
worksheet



Atoms/Molecules and Grams

- **Since 6.02×10^{23} particles = 1 mole
AND
1 mole = molar mass (grams)**
- **You can convert atoms/molecules to moles and then moles to grams! (Two step process)**
- **You can't go directly from atoms to grams!!!! You MUST go thru MOLES.**
- **That's like asking 2 dozen cookies weigh how many ounces if 1 cookie weighs 4 oz? You have to convert to dozen first!**

Calculations



**Everything must go through
Moles!!!**

Atoms/Molecules and Grams



How many atoms of Cu are present in 35.4 g of Cu?

$$\frac{35.4 \text{ g Cu}}{63.5 \text{ g Cu}} \times \frac{1 \text{ mol Cu}}{1 \text{ mol Cu}} \times 6.02 \times 10^{23} \text{ atoms Cu}$$

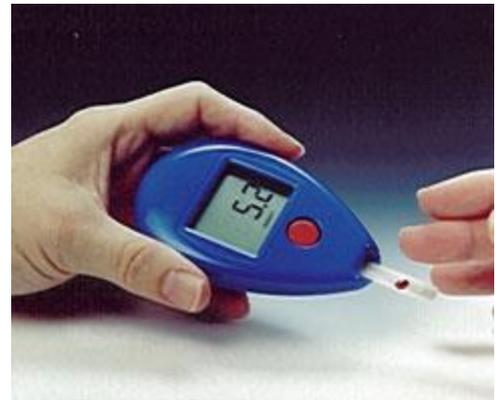
$$= 3.4 \times 10^{23} \text{ atoms Cu}$$

Learning Check!

How many atoms of K are present in 78.4 g of K?

Learning Check!

What is the mass (in grams) of 1.20×10^{24} molecules of glucose ($C_6H_{12}O_6$)?



Learning Check!

How many **atoms** of O are present in 78.1 g of oxygen?
Remember formula for Oxygen is O₂.

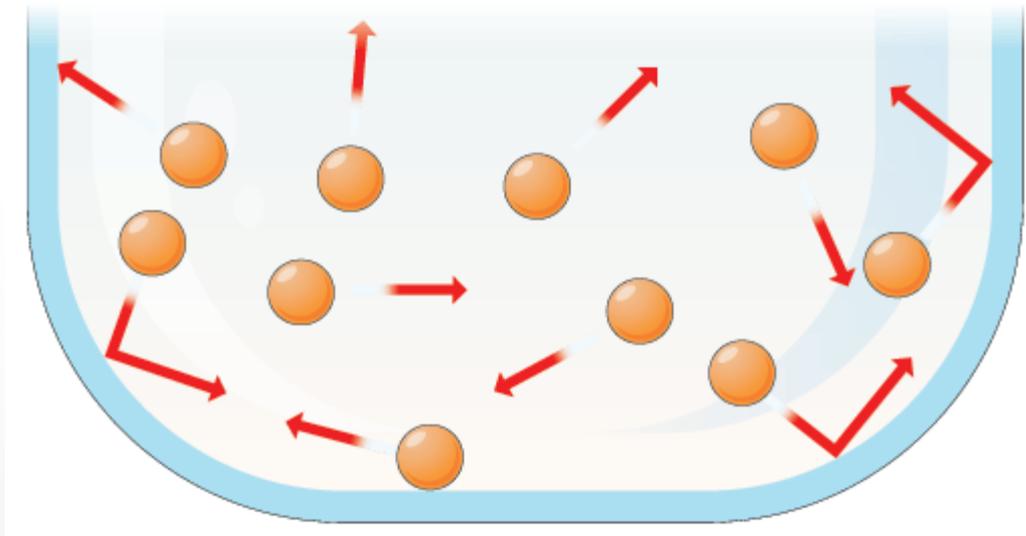
Do questions #16 to 22
on the
Moles, Molecules and
STP worksheet



Chaos

Gases

- Gases fill their containers
- Compressible
- Diffuse
- Temperature affects the Volume or Pressure or Both



Pressure

Pressure is force per Unit Area

SI unit for Pressure is Kilopascal (Kpa)

Which represents a force

of 1000N(newtons) on an area of 1m^2

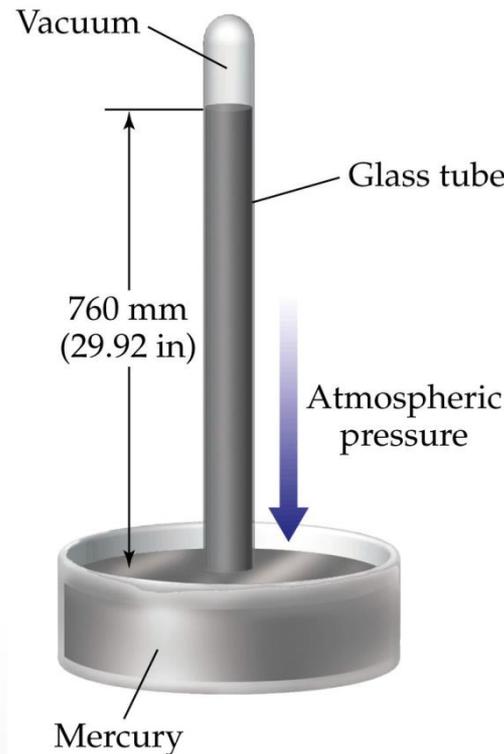
$$1\text{Kpa} = 1000\text{N}/\text{m}^2$$

Atmospheric pressure is the pressure exerted by the air.

At sea level $P=101\text{Kpa} = 760\text{mmHg}$

Standard Pressure = $101.325\text{Kpa} = (1\text{atm})$

Standard ambient pressure = 100Kpa



STP (standard Temperature and Pressure)

$$T = 0^{\circ}\text{C}$$

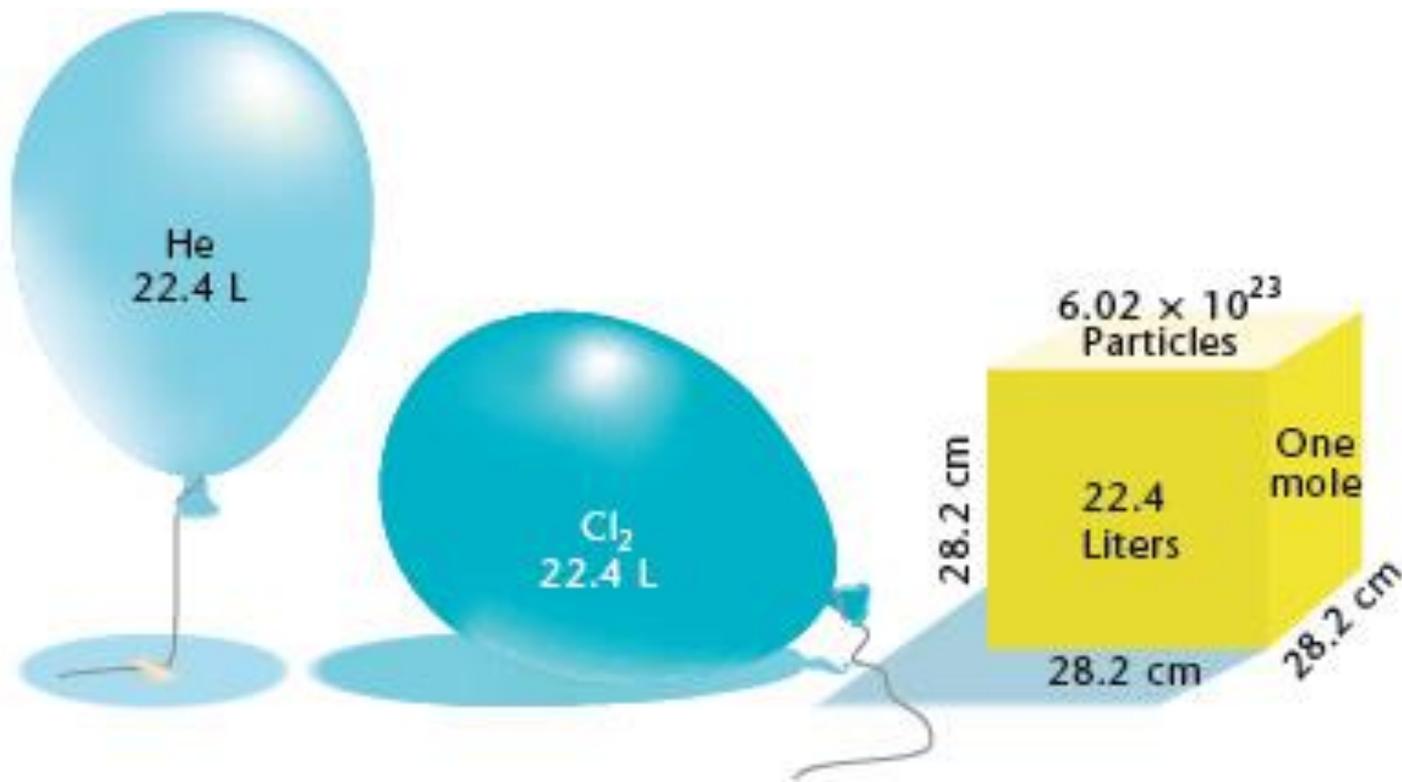
$$P = 101.325\text{kpa (1atm)}$$

SATP (standard ambient temp and pressure)

$$T = 25^{\circ}\text{C}$$

$$P = 100 \text{ Kpa}$$

1 mole of any gas has a volume of 22.4L at STP.



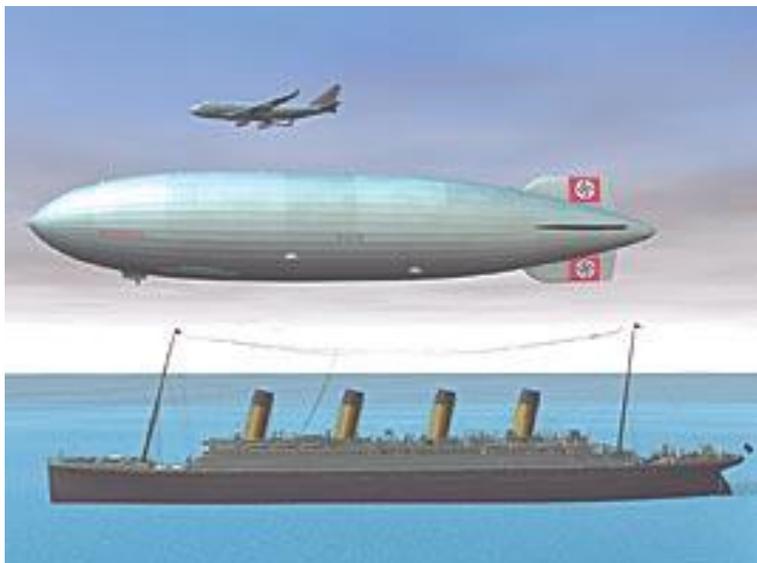


Volume:	22.4 L	22.4 L	22.4 L
Pressure:	1 atm	1 atm	1 atm
Temperature:	273 K	273 K	273 K
Quantity:	1 mole	1 mole	1 mole
Mass:	40.0 g	32.0 g	28.0 g

Same number of particles take up same amount of volume but will have different mass.

Example

How many moles of Hydrogen gas are in the 2×10^8 Liters used in the Hindenburg?



Example

How many liters of carbon dioxide are in 0.0237 moles.

Do Questions 23 to 30 on the Worksheet

MULTI-STEP CONVERSIONS NOTES

For Example:

a. What is the volume occupied by 50.0 g of $\text{NH}_3(g)$ at STP?

b. What is the mass of 1.00×10^{12} atoms of Cl?

c. How many Oxygen atoms are contained in 75.0 L of $\text{SO}_3(g)$ at STP?

For Example:

a. What is the volume occupied by 3.00 mol of ethanol, $\text{CH}_3\text{CH}_2\text{OH}(l)$?
($d = 0.790 \text{ g/mL}$)

b. How many moles of $\text{Hg}(l)$ are contained in 100 mL of $\text{Hg}(l)$? ($d = 13.6 \text{ g/mL}$)

c. What is the density of $O_2(g)$ at STP?

d. A 2.50 L bulb contains 4.91 g of a gas at STP. What is the molar mass of the gas?

e. $\text{Al}_2\text{O}_3(\text{s})$ has a density of 3.97 g/mL. How many atoms of Al are in 100mL of Al_2O_3 ?

Do mole conversions
work sheet.

Percent Composition

What is the percent composition of $C_5H_8NO_4$ (the glutamic acid used to make MSG monosodium glutamate), a compound used to flavor foods and tenderize meats?



