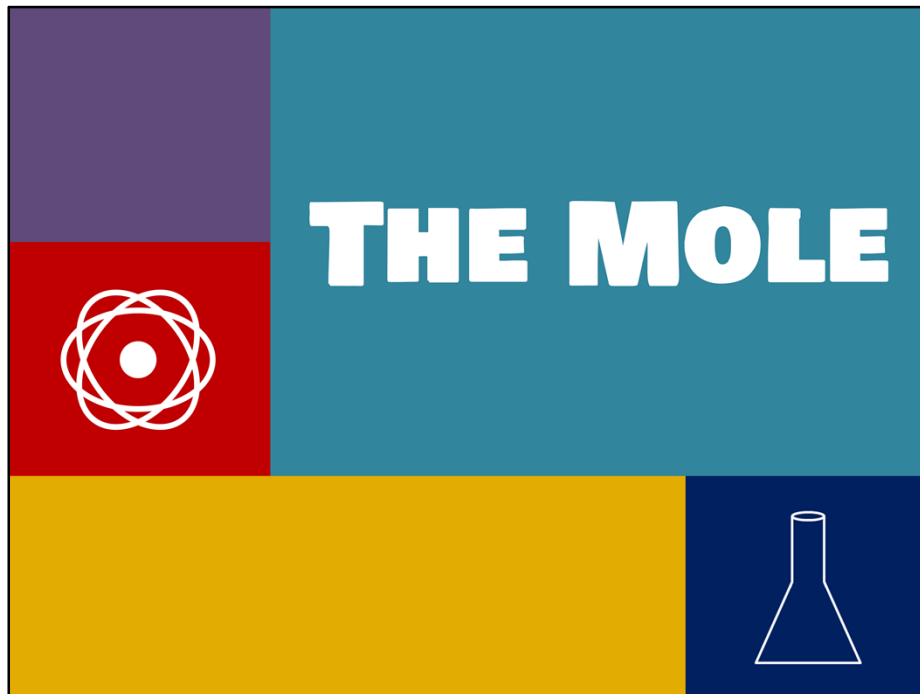


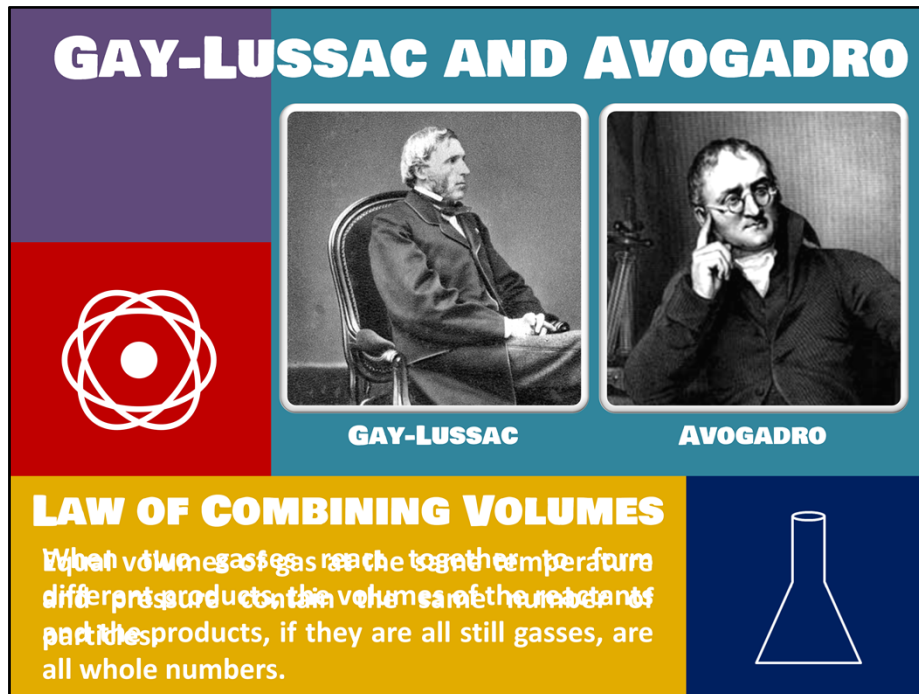
Module 5: Chemical Quantities and Composition
Topic 1 Content: The Mole and Molarity Presentation Notes



The Mole

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GAY-LUSSAC AND AVOGADRO




GAY-LUSSAC

AVOGADRO

LAW OF COMBINING VOLUMES

When volumes of gas react together at the same temperature and pressure, the volumes of the reactants and products, if they are all still gasses, are all whole numbers.



The history of the molar concept can be traced back to work done by Joseph Louis Gay-Lussac and Amedeo Avogadro in the 18th and 19th centuries. Joseph Louis Gay-Lussac's research stated that when two gasses react together to form different products, the volumes of the reactants and the products, if they are all still gasses, are all whole numbers. This was called the Law of Combining Volumes. According to Avogadro, equal volumes of gas at the same temperature and pressure contain the same number of particles. He never used the word mole, but he helped establish the groundwork for further defining the amount.

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The graphic is divided into four colored quadrants. The top-left quadrant is purple. The top-right quadrant is teal and contains the title 'WHAT IS A MOLE?' in white. Below the title, it shows 'PAIR' with two grey human figures, 'AVOGADRO'S NUMBER' with a grey box of white eggs, and 'DOZEN' with a grey box of white eggs. The bottom-left quadrant is yellow and contains the equation 'MOLE = 6.02 x 10²³'. The bottom-right quadrant is dark blue and contains a white outline of a flask. A white atomic symbol is in the middle-left quadrant.

Just as the word “pair” represents two and the word “dozen” represents twelve, the word “mole” represents a specific amount. In fact, it is a really LARGE amount. The word “molar” comes from the Latin term meaning “a large mass.” What amount does a mole signify? A mole is 6.02×10^{23} , which is also known as Avogadro's number. Just like a pair of twins or a dozen eggs, a mole is a number of something. In your study of chemistry, that “something” is atoms or molecules.

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HOW BIG IS A MOLE?

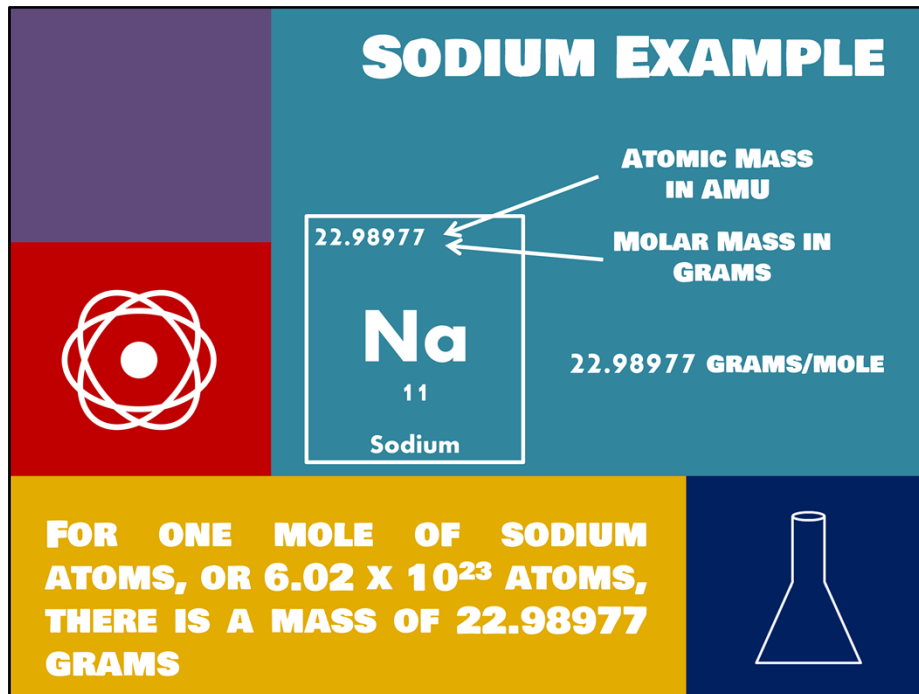
MOLAR MASS OF ELEMENT
= 1 TRILLION
1,000,000,000,000
ATOMIC MASS OF ELEMENT
= A MOLE
1 MOLE OF THE ELEMENT
602,214,150,000,000,000,000

6.02 x 10²³
THE NUMBER OF ATOMS OF AN ELEMENT IN A SAMPLE WITH A MASS IN GRAMS NUMERICALLY EQUAL TO THE ATOMIC MASS OF THE ELEMENT IN ATOMIC MASS UNITS.

The infographic is divided into four colored sections: a purple top-left section, a red bottom-left section containing a white atomic symbol, a yellow bottom section containing the value 6.02×10^{23} and its definition, and a dark blue bottom-right section containing a white outline of a flask.

How big is 6.02×10^{23} ? A trillion is shown here. A mole is a over six-hundred two sextillion, or almost a trillion trillions! Why is a mole so big? This number was determined experimentally based on the relationship between carbon's mass in atomic mass units and grams. Atoms are small. It takes a lot of these miniscule particles to make a measurable mass. Avogadro's number represents the number of atoms of an element in a sample with a mass in grams numerically equal to the atomic mass of the element in atomic mass units. What does this mean? It means that the molar mass of an element, which is equal to the element's atomic mass, is also equal to one mole of that element.

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SODIUM EXAMPLE

ATOMIC MASS IN AMU

MOLAR MASS IN GRAMS

22.98977

Na

11

Sodium

22.98977 GRAMS/MOLE

FOR ONE MOLE OF SODIUM ATOMS, OR 6.02×10^{23} ATOMS, THERE IS A MASS OF 22.98977 GRAMS

The diagram is a composite graphic. At the top left is a purple square. Below it is a red square containing a white atomic model. To the right of the red square is a white-bordered box representing a periodic table entry for Sodium (Na), with the atomic number 11 and the name 'Sodium'. Above the box is the number 22.98977. To the right of the box, two arrows point from the text 'ATOMIC MASS IN AMU' to the number 22.98977, and from 'MOLAR MASS IN GRAMS' to the number 22.98977. Below the box is the text '22.98977 GRAMS/MOLE'. At the bottom left is a yellow square with the text 'FOR ONE MOLE OF SODIUM ATOMS, OR 6.02×10^{23} ATOMS, THERE IS A MASS OF 22.98977 GRAMS'. At the bottom right is a dark blue square containing a white outline of a flask.

Take a look at an example for a single element. Here you see the periodic table information for the element sodium. Sodium has an atomic symbol of eleven and an atomic mass of 22.98977 amu, and a molar mass 22.98977 grams per mole. This means that for one mole of sodium atoms, or 6.02×10^{23} atoms, there is a mass of 22.98977 grams.

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SODIUM CHLORIDE EXAMPLE

NaCl

↑ ↑

MOLAR MASS IN GRAMS

22.98977

Na

11

Sodium

35.453

Cl

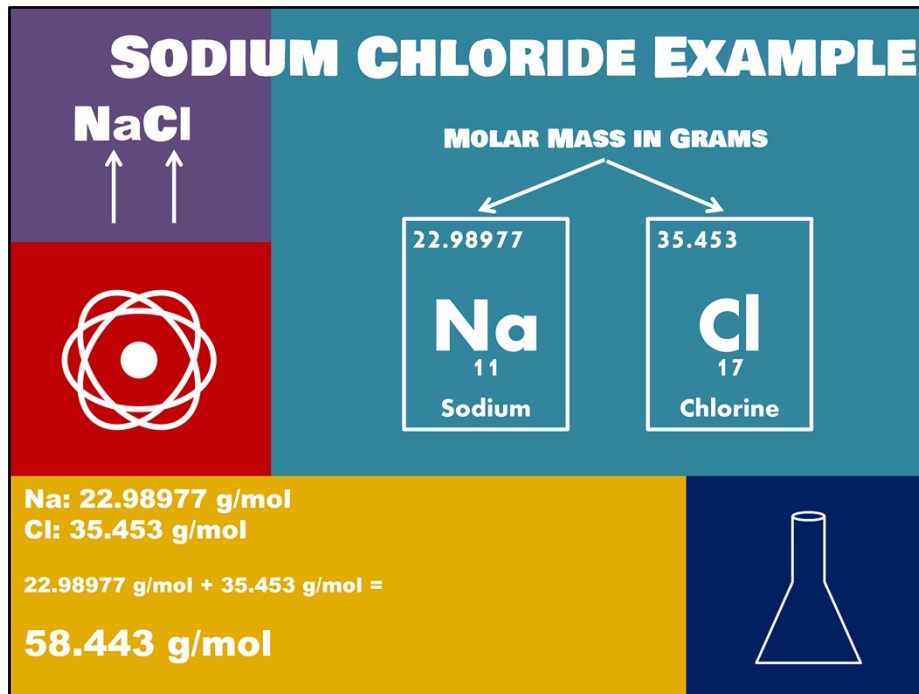
17

Chlorine

Na: 22.98977 g/mol
Cl: 35.453 g/mol

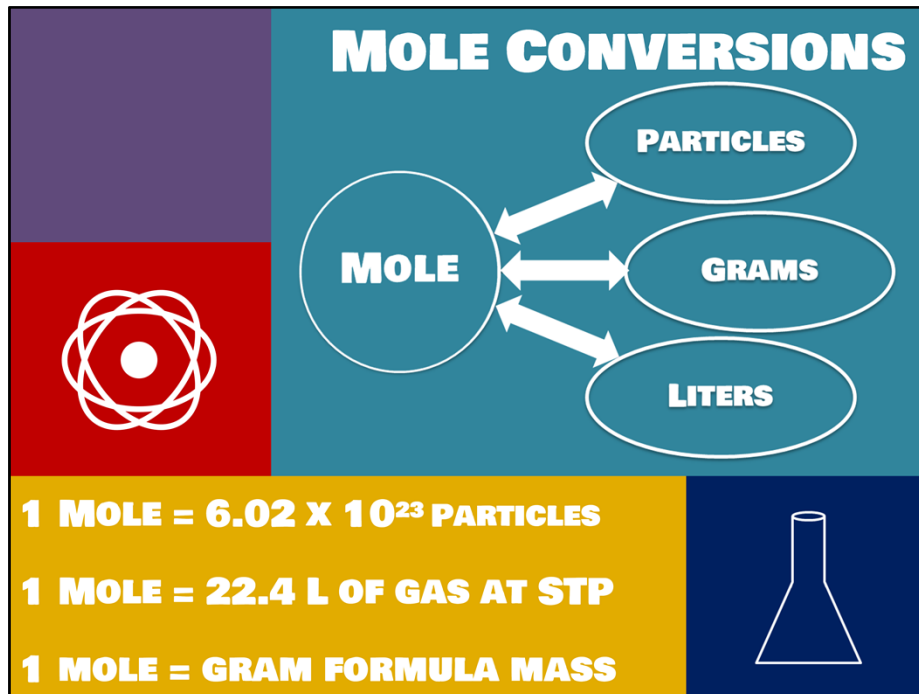
22.98977 g/mol + 35.453 g/mol =

58.443 g/mol



Now, take a look at an example for a common compound, sodium chloride, or table salt. In this compound, there is one sodium atom and one chlorine atom. Here, you see the periodic table information for the elements sodium and chlorine. From this information, you can obtain each of these elements' molar mass in grams per mole. Using your knowledge of determining molar mass, you know that to determine the compound's molar mass, you need to add the molar mass for each of the atoms involved in the compound. Once you complete that calculation, you will find that one mole, or 6.02×10^{23} formula units, of the compound sodium chloride has a molar mass of 58.443 grams per mole.

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In chemistry, you will convert from mass to moles, particles to moles, and even volume to moles based on the relationships between particles, grams, moles, and liters. This mole conversion map provides a great visual way to plan out your problem solving strategy.

When completing conversions, you will need to use dimensional analysis. To do this, it is important to know the conversion value of moles to particles, grams, and liters:

- One mole equals 6.02×10^{23} particles.
- One mole equals 22.4 liters of gas at standard temperature and pressure conditions, abbreviated as STP. The volume conversion from moles to liters is specifically used when gases are at standard temperature and pressure conditions.
- One mole is equal to the molar mass of an element.

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WHICH "PARTICLE" TO USE?

CONVERSION SCENARIO	PARTICLE TERM	EXAMPLE
COVALENT COMPOUND	MOLECULE	WATER - H ₂ O
IONIC COMPOUND	FORMULA UNIT	SODIUM BIFLUORIDE
MONATOMIC ELEMENT	ATOM	CARBON
IONS	ION	PHOSPHATE

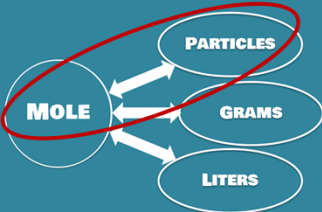
MOLE = 6.02 X 10²³ PARTICLES

So far, you have seen the broad term “particles” used to describe the components of a mole. Depending on the scenario, the term “particle” is replaced by one of the following terms: atoms, molecules, formula units, or ions. If the conversion is related to a covalent compound, then the term molecule should be used. If the conversion is related to an ionic compound, then the term formula unit should be used. If the conversion is related to a monatomic element, like carbon, then the term atom should be used. Finally, if the conversion is related to an ion, like phosphate, then the term ion should be used. All of these words represent the particle unit for these specific particle types.


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EXAMPLE 1

HOW MANY ATOMS OF NEON ARE IN 4.33 MOLES OF NEON?




1 MOLE = 6.02×10^{23} ATOMS

$$\frac{4.33 \text{ mol Ne}}{1 \text{ mol}} \times \frac{6.02 \times 10^{23} \text{ atoms Ne}}{1 \text{ mol}} = 2.61 \times 10^{24} \text{ atoms Ne}$$


Take a look at this example of a conversion scenario. Pretend that you have a sample of 4.33 moles of neon and you are being asked to find the number of atoms in the sample. Refer back to the mole map when determining the steps of the scenario. This problem uses particles and moles. Remember, one mole equals 6.02×10^{23} atoms. To solve this, you will need to use dimensional analysis.

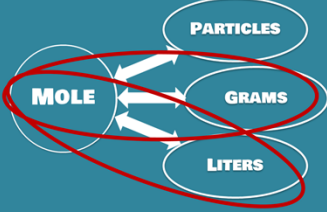
When writing out the dimensional analysis, add the given part of the problem first. Here, it is 4.33 moles of neon. Since you know that there are 6.02×10^{23} atoms in one mole, then next step is to add this information. You can then cancel out the units and solve the problem by multiplying 4.33 times 6.02×10^{23} to find that 4.33 moles of neon is equal to 2.61×10^{24} atoms of neon.

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EXAMPLE 2

HOW MANY GRAMS OF CH₄ WOULD IT TAKE TO FILL A 15.0 LITER TANK AT STP?



LITERS TO MOLES TO GRAMS

$$\frac{15.0 \text{ L CH}_4}{22.4 \text{ L CH}_4} \times \frac{1 \text{ mol CH}_4}{1 \text{ mol CH}_4} \times \frac{16.4 \text{ g CH}_4}{1 \text{ mol CH}_4} = 10.7 \text{ g CH}_4$$



In this example, you are being asked to determine the number of grams of methane it would take to fill a 15.0 liter tank at STP. Dimensional analysis will be used to solve this, but this will actually involve the conversion from liters to moles and then from moles to grams.

Both conversions are important because there is not a direct relationship between liters and grams. When setting up this equation, first write the given information, 15.0 liters of CH₄, which is methane. The equivalence of moles to liters is one mole of CH₄ equals 22.4 liters of CH₄ at standard temperature and pressure. The problem is asking for the amount of grams of methane it will take to fill the tank, so now it is time to convert moles to grams.

You know that one mole equals the molar mass of CH₄. So, multiply by the gram formula mass of CH₄, which is 16.4 grams CH₄, over one mole of CH₄. Now it is time to solve for the grams of methane. On the left-hand side, “liter of CH₄” will cancel out first. Then, “mole CH₄” will cancel out. After you multiply and divide going from left to right, the answer is 10.7 grams of CH₄. This shows that it will take 10.7 grams of methane to fill a 15.0 liter tank at standard temperature and pressure.