QUANTITIES and RATIOS

- Mole
- Amount of substance
- Molar mass
- Molar volume
- Molar ratios
- Molar concentration
- Mass fraction

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22 Molar quantities

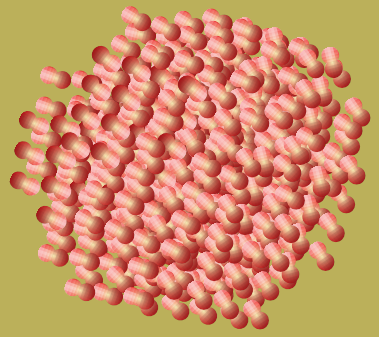
$$M(Na) = \frac{m(Na)}{n(Na)}$$

$$V_m(O_2) = \frac{V(O_2)}{n(O_2)}$$

KEY TOPICS

1. What are molar quantities?
2. Why do we use molar quantities rather than mass and volume of substances?
3. What is the difference between mass fraction and percent composition by mass?
4. What is the molar volume of gases at STP?

1 molecule



1 mole

602 214 908 670 000 000 000 000 molecules

KEY WORDS

- Atomic mass unit
- Mole
- Amount of substance
- Molar mass
- Mass fraction
- Molar volume

WHAT ARE MOLAR MASS AND MOLAR VOLUME?

In system SI (**S**ystème **I**nternationale) the basic units of mass and volume are a kilogram „kg“ and a cubic meter „m^3“. For chemists these units are not very useful as in chemical reactions the reacting species are atoms, ions, molecules which are very, very small particles and their number is giant. For this reason in chemistry some specific units and quantities have been introduced:

- **atomic mass unit *u*** – a non-SI unit of mass equal to 1/12 of the mass of a nonbonded carbon-12 atom. This is the basic unit of mass used in chemistry;
- **mole *mol*** – a SI unit which means exactly $6{,}0221490867.10^{23}$ entities (atoms, molecules, ions, atomic groups, electrons, etc.) of a substance (simple substance, chemical compound, identical ions, electrons). (It is the same as for example a hundred, a dozen, etc. We know that a hundred people means exactly 100 men, a dozen chairs are exactly 12 chairs, etc.) So 1 mole of any substance are exactly $6{,}0221490867.10^{23}$ entities. This is exactly the number of atoms in 0,012 kg of carbon-12. This number is known as the **Avogadro's number N_A.** 1 mole of oxygen are exactly $6{,}0221490867.10^{23}$ molecules of O_2, 1 mole of carbon are exactly $6{,}0221490867.10^{23}$ carbon atoms, 1 mole of sodium ions are $6{,}0221490867.10^{23}$ ions Na^+, etc.;
- **amount of substance *n*** – a quantity which accounts for the number of entities in a sample of a substance with mass *m*. It is equal to the number of moles of this substance corresponding to its mass. For example an amount of substance of sodium atoms *n*(Na) = 2 moles are $2.6{,}0221490867.10^{23}$ sodium atoms. (imagine how difficult would be to count these atoms one by one);

- **molar mass *M*** – the mass in grams of $6{,}0221490867.10^{23}$ entities (1 mole) building up a substance. It is denoted with the symbol ***M*** followed by the chemical formula of the substance in brackets (for example $M(O_2)$, $M(H_2O)$). The unit is g/mol. If the mass (in g) of ***n*** moles of a substance is ***m*** its molar mass is ***M = m/n***:

THE MASS OF 1 MOLE OF A SUBSTANCE IS CALLED MOLAR MASS *M*.
It is equal to the ratio of the mass of the substance *m* to its amount of substance *n*:

$$M(A) = \frac{m(A)}{n(A)}$$

The molar mass of a substance is numerically identical with its relative molecular mass M_r:
For example: $M_r(H_2) = 2$ and $M(H_2) = 2$ g/mol; $M_r(H_2O) = 18$ and $M(H_2O) = 18$ g/mol.

Remember that the molecular mass is too small to be measured (it is the mass of one molecule) but the molar mass is something measurable as this is the mass of a giant quantity of molecules – exactly $6{,}0221490867.10^{23}$ molecules. How giant is this number? Imagine that all the people in the World (now about 7,5 milliards) count one molecule each second. The contemporary Earth population will finish the counting of the molecules in 1 mole of any substance after about 2,5 millions of years!

PROBLEM! **What is the molar mass of $CaCl_2$ if the mass of 2,5 moles of $CaCl_2$ is 277,5 g?**

SOLUTION: The mass of $CaCl_2$ is $m(CaCl_2)$ = 277,5 g. The amount of substance of $CaCl_2$ is n = 2,5 moles. The molar mass $M(CaCl_2)$ is:

$$M(CaCl_2) = \frac{m(CaCl_2)}{n(CaCl_2)} = \frac{277,5}{2,5} = 111 \text{ g/mol}$$

The molar mass can be also calculated using the relative atomic masses of calcium and chlorine:

$$M_r(CaCl_2) = A_r(Ca) + 2\,A_r(Cl) = 40 + 2..35,5 = 111$$

ANSWER: **The molar mass of $CaCl_2$ is 111 g/mol**

PROBLEM! **What is the mass of 5 moles of NaOH?**

SOLUTION: The mass $m(NaOH) = M(NaOH).n(NaOH)$

The amount of substance of NaOH is n = 5 moles.

The molar mass is calculated using the relative atomic masses of sodium, oxygen and hydrogen:

$$M_r(NaOH) = A_r(Na) + A_r(O) + A_r(H) = 23 + 16 + 1 = 40$$

It follows that the molar mass of NaOH is $M(NaOH)$ = 40 g/mol

The mass of 5 moles of NaOH is $m(NaOH) = 40.5 = 200$ g

ANSWER: **The mass of 5 moles of NaOH is 200 g.**

- **mass fraction *w*** − the ratio of the mass of an element in 1 mole of a compound to the molar mass of the compound. The sum of the mass fractions of the elements in a compound is always 1. If the values are multiplied by 100 the quantity is called **percent composition by mass *w%***. In brackets is always written the chemical symbol of the element.

PROBLEM!

What are the mass fractions of hydrogen and oxygen in water?
What is the percent composition by mass of water?

SOLUTION: **1.** Calculate the relative molecular mass of water:

$$M_r(H_2O) = 2A_r(H) + A_r(O) = 2.1 + 16 = 18$$

2. Determine the molar mass of water − it is numerically identical with its relative molecular mass:

$$M(H_2O) = 18\ g/mol$$

3. Calculate the mass fraction of oxygen. In 1 mole of H_2O molecules there is 1 mole of oxygen atoms which are exactly 16 g (***m*(O)** = ***n*(O)**. ***M*(O) = 1.16 = 16 g).** So:

$$w(O) = m(O)/M(H_2O) = 16/18 = 0,89$$

4. Calculate the mass fraction of hydrogen. In 1 mole of H_2O molecules there are 2 moles of hydrogen atoms which are exactly 2 g (***m*(H)** = ***n*(H)**. ***M*(H) = 2.1 = 2 g)**. So:

$$w(H) = m(H)/M(H_2O) = 2/18 = 0,11$$

Check: $w(O) + w(H) = 0,89 + 0,11 = 1$

5. Determine the percent composition of water:

$$w\%(O) = w(O).100 = 0,89.100 = 89\ \%; \qquad w\%(H) = w(H).100 = 0,11.100 = 11\ \%$$

Check: $w\%(O) + w\%(H) = 89 + 11 = 100\ \%$

ANSWER: **Water is composed of 89 % oxygen and 11 % hydrogen (by mass).**

- **molar volume *V*** – the volume occupied by $6{,}0221490867.10^{23}$ entities (1 mole) building up a substance. It is denoted by $\boldsymbol{V}_m$ and in brackets the chemical formula of the substance. It is measured in ℓ/mol or dm^3/mol (The SI-unit is m^3/mol, but it is rarely used):

THE VOLUME OF 1 MOLE OF A SUBSTANCE IS CALLED MOLAR VOLUME V_m.
It is equal to the ratio of the volume of the substance *V* to its amount of substance *n*:

$$V_m(A) = \frac{V(A)}{n(A)}$$

The molar volumes of solid and liquid substances is different for the various substances. For example $V_m(H_2O)$ = 18 cm^3/ mol, V_m(ethanol) = 58 cm^3/ mol. Unlike solids and liquids the molar volume of the rarefied gases depends on the pressure and the temperature but not on the nature of gases. At STP (**S**tandard **P**ressure and **T**emperature – 0°C and 1 atm = 101 325 Pa) the molar volume of all gases is the same – 22,41 dm^3/mol (1 dm^3 = 1 ℓ).

In the early 19th century Amedeo Avogadro formulated a law, named in his honor the ***Avogadro's Law:***

EQUAL VOLUMES OF DIFFERENT RAREFIED GASES CONTAIN AN EQUAL NUMBER OF MOLECULES OR ATOMS AT THE SAME CONDITIONS (PRESSURE AND TEMPERATURE).

This means that the volume of 1 mole of oxygen O_2 at STP is equal to the volume of 1 mole of hydrogen H_2, 1 mole of carbon monoxide CO, 1 mole of carbon dioxide CO_2, 1 mole of helium He etc. So the molar volume of gases at STP is always 22,41 dm^3/mol. That is the volume occupied by $6{,}0221490867.10^{23}$ molecules of any rarefied gas at STP!

PROBLEM!

What are the molar volumes of hydrogen H_2, oxygen O_2 and carbon dioxide CO_2 at STP if:

a) 3 moles of hydrogen H_2 occupy 67,2 dm^3;

b) 7 moles of oxygen O_2 occupy 156,8 dm^3

c) 5 moles of carbon dioxide CO_2 occupy 112 dm^3

SOLUTION: The molar volume V_m of any of the gases is equal to the ratio of its volume V and its amount of substance n:

a) The volume of hydrogen $V(H_2) = 67,2\ dm^3$ and its amount of substance is $n(H_2) = 3$ moles. So:

$$V_m(H_2) = \frac{V(H_2)}{n(H_2)} = \frac{67,2}{3} = 22,4\ dm^3/mol$$

b) The volume of oxygen $V(O_2) = 156,8\ dm^3$ and its amount of substance is $n(O_2) = 7$ moles. So:

$$V_m(O_2) = \frac{V(O_2)}{n(O_2)} = \frac{156,8}{7} = 22,4\ dm^3/mol$$

a) The volume of carbon dioxide $V(CO_2) = 112\ dm^3$ and its amount of substance is $n(CO_2) = 5$ moles. So:

$$V_m(CO_2) = \frac{V(CO_2)}{n(CO_2)} = \frac{112}{5} = 22,4\ dm^3/mol$$

ANSWER: 1 mole ($6,0221490867.10^{23}$ molecules) **of hydrogen H_2, oxygen O_2 or carbon dioxide CO_2 at STP occupies a volume of 22,4 dm^3.**

CAN YOU ANSWER THESE QUESTIONS ?

1. Why do chemists use the atomic mass unit but not the SI-unit (kg) for the weight of 1 molecule of a chemical compound?
2. What is the number of atoms in 1 mole of sodium?
3. Is the number of molecules in 2 moles of hydrogen equal to the number of atoms in 2 moles of sodium? Why?
4. How many sodium ions are there in 3 moles of table salt?
5. The relative molecular mass of sodium base NaOH is 40. What is its molar mass?
6. What is the percent composition by mass of hydrogen chloride HCl if the mass fraction of hydrogen is 0,027?
7. What is the molar volume of gases at STP?
8. Do 3 moles of oxygen O_2 have the same volume at STP as 3 moles of helium He?
9. Is at STP the volume of 2 moles of neon Ne twice as large as the volume of 1 mole of chlorine Cl_2?
10. Why is the molar volume of gases at STP identical?

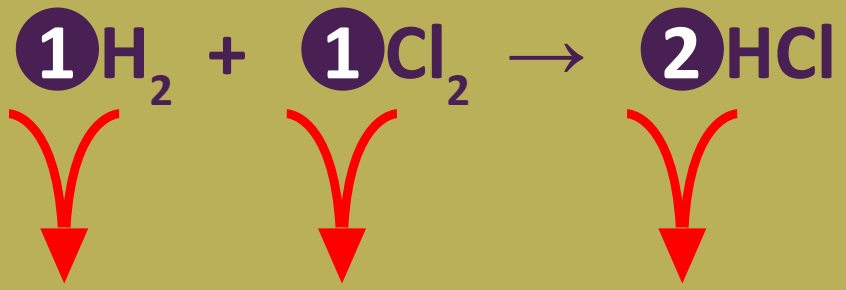
23 Mole ratios

KEY TOPICS

1. What are mole ratios?
2. What are mole ratios used for in chemistry?
3. Why are mole ratios so important for chemists?

KEY WORDS

- Mole ratios
  (molar ratios)
  (mole-to-mole ratios)



WHAT ARE MOLE RATIOS and WHAT ARE THEY USED FOR?

In chemical reactions simple substances or chemical compounds react to produce other simple substances or other compounds. Independently of the type of the reaction always a definite number of entities (molecules, atoms, ions, etc.) of a substance react with a definite number of entities of other substances to produce definite numbers of entities of one or more new substances. A balanced chemical equation shows exactly the „proportion“ of the quantities of reactants. For example in the reaction of water synthesis exactly 2 molecules of hydrogen H_2 react with just 1 molecule of oxygen O_2 to produce 2 molecules of water:

$$\mathbf{2H_2 + O_2 \rightarrow 2H_2O}$$

2 molecules of H_2 react with 1 molecule of O_2 to produce 2 molecules of water

But the measurable quantity is the amount of substance corresponding to a mass *m* or a volume *V* of any reactant or product. If we multiply both sides of the equation by the Avogadro's number (the number of particles in 1 mole) the coefficients will be equal to the numbers of moles of the reactants and the products:

$$\mathbf{2.}6{,}0221490867.10^{23}\,\mathbf{H_2} + \mathbf{1.}6{,}0221490867.10^{23}\,\mathbf{O_2} \rightarrow \mathbf{2.}6{,}0221490867.10^{23}\,\mathbf{H_2O}$$

or: **2 moles of H_2 react with 1 mole of O_2 to produce 2 moles of H_2O**

If 4 moles of hydrogen molecules H_2 react withe 2 moles of oxygen molecules O_2 4 moles of water molecules H_2O will be produced, etc. The determination of the quantity of the reactants that will produce the desired quantity of any product is a key step in any industrial process or laboratory experimentation. **Mole ratios** are used as a conversion factor between reactants and products to make that step easy.

MOLES RATIOS OF THE COMPONENTS OF A CHEMICAL REACTION are the ratios of the amounts of the reaction components. They are equal to the coefficients in the balanced chemical equation of the reaction.
Moles ratios are also called molar ratios or mole-to-mole ratios.

Mole ratios may concern any reactants or products. For example for the reaction of synthesis of water one can write:

$$n(H_2) : n(O_2) : n(H_2O) = 2 : 1 : 2$$
$$n(H_2) : n(O_2) = 2 : 1$$
$$n(H_2) : n(H_2O) = 2 : 2 = 1 : 1 \text{ (always the smallest possible ratio is used)}$$
$$n(O_2) : n(H_2O) = 1 : 2$$

So a mole ratio is the ratio of the moles of one substance to the moles of another substance in a balanced chemical equation. For example for the reaction of synthesis of ammonia NH_3:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

the ratios between the amount of the reaction components are:

$$n(N_2) : n(H_2) : n(NH_3) = 1 : 3 : 2$$
$$n(N_2) : n(H_2) = 1 : 3$$
$$n(N_2) : n(NH_3) = 1 : 2$$
$$n(H_2) : n(NH_3) = 3 : 2$$

The usefulness of the mole ratios becomes obvious with the help of a simple example:

PROBLEM! **In the reaction of zinc Zn with diiron trioxide Fe_2O_3 the products are zinc oxide and iron. How many kg of Fe_2O_3 are needed to produce 1 kg of iron? (A_r (Fe) = 56, A_r(O)=16)**

SOLUTION: **1.** Express the chemical equation of the reaction:

$$\mathbf{3Zn + Fe_2O_3 \rightarrow 3ZnO + 2Fe}$$

2. Write down the mole ratio of Fe_2O_3 and Fe:

$$\mathbf{n(Fe_2O_3) : n(Fe) = 1 : 2}$$ (from 1 mole of Fe_2O_3 2 moles of Fe are produced)

3. Determine the molar masses of iron Fe and diiron trioxide Fe_2O_3:

$$A_r(Fe) = 56 \quad \text{and} \quad \mathbf{M(Fe) = 56\ g/mol}$$

$$M_r(Fe_2O_3) = 2A_r(Fe) + 3A_r(O) = 2.56 + 3.16 = 160 \quad \text{and} \quad \mathbf{M(Fe_2O_3) = 160\ g/mol}$$

4. Calculate the amount of substance of the product Fe:

$$\mathbf{n(Fe)} = m(Fe) : M(Fe) = 1\,000 : 56 = \mathbf{17{,}86\ moles}$$

5. Use the mole ratio to calculate the amount of Fe_2O_3 required to produce 17,86 moles of iron:

$$n(Fe_2O_3) : 17{,}86 = 1 : 2$$

$$\mathbf{n(Fe_2O_3) = (1.17{,}86)/2 = 8{,}93\ moles}$$

6 Calculate the mass of 8,93 moles of diiron trioxide Fe_2O_3:

$$\mathbf{m(Fe_2O_3) = n(Fe_2O_3).\ M(Fe_2O_3) = 8{,}93.160 = 1\,428{,}8\ g \approx 1{,}429\ kg}$$

ANSWER: **1 kg of iron Fe is produced from 1,429 kg of Fe_2O_3**

Note that it is impossible to calculate the indispensable mass of the reactant without using the amount of substances and the balanced chemical equation of the reaction (i.e. the mole ratio).

CAN YOU ANSWER THESE QUESTIONS ?

1. What do mole ratios stand for?
2. Why should be a chemical equation balanced to determine the mole ratios of its components?
3. How to calculate the amount of the product of a reaction?
4. How to calculate the mass of a reactant needed to produce the desired mass or volume of a reaction product?
5. Is it right to express a mole ratio as 2 : 2? Why?
6. The moles ratios of the unknown chemical reaction $A + B \rightarrow C$ are $n(A) : n(B) : n(C) = 1:1:1$. Can you give examples of such reactions?
7. Sulfur dioxide burns and transforms into sulfur trioxide. The moles ratios of the reaction components are: $n(SO_2) : n(O_2) : n(SO_3) = 2 : 1 : 2$. Is it true that 10 moles of SO_2 transform into 1O moles of SO_3? Why? How many dm^3 of oxygen are needed to produce 10 moles of SO_3 at STP?

24 Molar concentration

KEY TOPICS

1. Why is it important to know solutions composition?
2. What is a molar concentration (molarity) of a solution?
3. How to calculate the molarity of a solution?

$$M = \frac{n}{V}$$

KEY WORDS

- Solution
- Solvent
- Solute
- Concentration
- Molar concentration (molarity)

WHY IS IT IMPORTANT TO KNOW SOLUTIONS COMPOSITION?

Simple substances and chemical compounds are pure substances. A piece of pure iron is made up only of iron atoms. Pure water contains only H_2O molecules. In a bottle with pure oxygen there are only O_2 molecules, etc. But often when two pure substances react the products form mixtures of two or more substances. For example if a piece of sodium is put into a test tube with water (both sodium and water are pure substances) bubbles of hydrogen rise as H_2 is evolved in the air and the solid sodium disappears as sodium base is formed: $2Na + 2H_2O \rightarrow 2NaOH + H_2\uparrow$. The liquid in the test tube is not anymore a pure substance. It is a homogenous mixture of sodium base and water, i.e. it is a solution of sodium base in water. Water is the **solvent** and NaOH is the **solute**. It is obvious that the quantity of the dissolved NaOH may vary depending on the mass of the solid sodium. The **concentration** of a solution is a quantity that accounts for the amount (grams, moles) of the solute in the solution. The most common way is to evaluate the amount of the solute (number of moles) in 1 litre (1 dm^3). It is called **molar concentration** of the solution:

MOLAR CONCENTRATION of a solution is the amount of moles of a solute per 1 litre of the solution.
It is called also MOLARITY of the solution.
It is denoted by *M*.
The molar concentration is equal to the ratio of the number of moles *n* of the solute and the volume *V* of the solution:

$$M = \frac{n}{V}$$

Pay attention to the similarity in the notations of molar mass and molar concentration – both are denoted as *M*. But the molar mass is expressed in g/mol (the mass of 1 mole of a substance) while the molar concentration is expressed in mol/ℓ (the ratio of the moles of a solute and the volume of the solution). For example the molar mass of sodium base is denoted as *M*(NaOH). The molarity of a solution of sodium base containing for example 0,5 moles per litre is denoted as 0,5 *M* NaOH.

TO REMEMBER:

M_r(A) – *relative molecular mass* of the substance A (dimensionless) **M_r(NaOH) = 40**

M(A) – *molar mass* of the substance A (g/mol) **M(NaOH) = 40 g/mol**

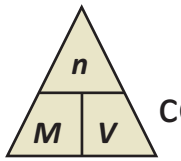
M – *molar concentration* (molarity) of the substance A (mol/ℓ).

The value of *M* is written before the symbol *M*.

The chemical formula of A is written after the symbol *M*.

1,5 *M* NaOH refers to a solution of NaOH with a molar concentration of 1,5 mol/ℓ

On an industrial scale as well as in the laboratory the determination of solutions concentrations, the preparation of solutions with definite concentrations or the determination of the volume of a solution with definite concentrations are key steps of any industrial process or experimentation.

The „magic“ triangle 

could make that easy and even fun! Cover up the symbol of the quantity you want to determine an calculate its value!

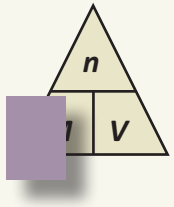
PROBLEM!

What is the molar concentration of a solution containing 222 g of calcium dichloride if its volume is:

a) 2 ℓ; b) 4 ℓ; c) 1 ℓ

GIVEN: the mass of the solute *m* (222 g) and the volume of the solution *V* (2 ℓ, 4 ℓ, 1 ℓ)
TO FIND: the molar concentrations M:

$$M = \frac{n}{V}$$



SOLUTION: 1. Convert the mass m (g) to amount of substance n (moles):

$M_r(CaCl_2) = A_r(Ca) + 2A_r(Cl) = 40 + 2.35{,}5 = 111$ and $M(CaCl_2) = 111$ g/mol

$n(CaCl_2) = m(CaCl_2)/M(CaCl_2) = 222/111 = 2$ moles

2. Calculate the molar concentrations of the solutions of $CaCl_2$:

a) $M\ CaCl_2 = n(CaCl_2)/V = 2/2 = 1$ mol/ℓ

b) $M\ CaCl_2 = n(CaCl_2)/V = 2/4 = 0{,}5$ mol/ℓ

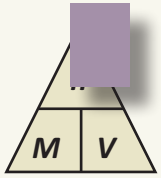
b) $M\ CaCl_2 = n(CaCl_2)/V = 2/1 = 2$ mol/ℓ

ANSWER: The molar concentration of the solution containing 222 g of $CaCl_2$ in 2 ℓ is 1 mol/ℓ.
If the quantity of $CaCl_2$ is the same but the volume is twice as large the molar concentration drops to 0,5 mol/ℓ.
If the quantity of $CaCl_2$ is the same but the volume is two times smaller the molar concentration rises to 2 mol/ℓ.

PROBLEM! **What mass of NaCl is needed to prepare 2 ℓ of 0,1 M solution?**

GIVEN: the molarity of the solution *M* (0,1) and the volume of the solution *V* (2 ℓ)
TO FIND: the mass *m* of the solute:

$$n = M.V$$
$$m = n.M(\text{NaCl})$$



SOLUTION: 1. Calculate the amount of substance of NaCl in 2 ℓ of 0,1 M solution:

$$n(\text{NaCl}) = M.V = 0{,}1.2 = 0{,}2 \text{ moles}$$

2. Calculate the molar mass of NaCl:

$M_r(\text{NaCl}) = A_r(\text{Na}) + A_r(\text{Cl}) = 23 + 35{,}5 = 58{,}5$ **So M(NaCl) = 58,5 g/mol**

3. Calculate the mass of 0,2 moles of NaCl:

$$m(\text{NaCl}) = M(\text{NaCl}).\ n(\text{NaCl}) = 0{,}2.58{,}5 = 11{,}7 \text{ g}$$

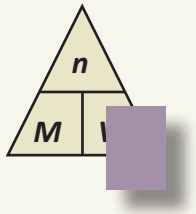
ANSWER: To prepare 2 ℓ of 0,1 M NaCl solution 11,7 g of NaCl must be dissolved in enough water to make 2 ℓ of the solution.

PROBLEM!

What is the volume of a 1,5 M KI solution if it contains 100 g of KI?

GIVEN: the molarity of the solution (1,5 M) and the mass of the solute *m* (100 g)
TO FIND: the volume of the solution:

$$V = \frac{n}{M}$$



SOLUTION: 1. Convert the mass *m* (g) of KI into amount of substance *n* (moles) of KI:

$M_r(KI) = A_r(K) + A_r(I) = 39 + 127 = 166$ **So M_r(KI) = 166 g/mol**

$n(KI) = m(KI)/M(KI) = 100/166 = 0,6$ moles

2. Calculate the volume of the 1,5 M solution containing 0,6 mole of KI:

$V = n(KI)/M = 0,6/1,5 = 0,4$ ℓ = 400 ml

ANSWER: The volume of a 1,5 M solution containing 100 g of KI is 400 ml.

CAN YOU ANSWER THESE QUESTIONS ?

1. What is molar concentration of a solution?
2. In 2 litres of a solution are 2 moles of a substance. Is this a 1 M solution?
3. The molarity of solution A is 2 mol/ℓ. The molarity of solution B is 0,5 mol/ℓ. Is the amount of the dissolved substance in 1 litre of solution A greater than the amount of the dissolved substance in 1 litre of solution B?
4. Is the mass of NaCl in 1 litre of 1 M solution equal to the mass of KCl in 1 litre of 1 M solution?
5. Do 2 litres of a 1 M solution of NaOH contain the same amount of substance as 1 litre of a 2 M solution of NaOH?
6. One tea spoon of table salt is about 10 g. How many tea spoons are needed to prepare 1 litre of 0,1 M solution of table salt? (M(NaCl) = 58,5 g)

Answer: about 1/2 of a tea spoon

PROJECTS

1. THE MOLE – HISTORY

Read and find out more about the „invention“ of mole. Why is this quantity so benefit for chemists?

2. VOLUME OF GASES

Compare the molar volumes of different gases at different pressures and temperatures (use data from reference books). Explain why equal amounts of different gases at STP occupy the same volume – 22,4 ℓ.

3. OCEAN, SEAS, RIVERS, LAKES – NATURAL SOLUTIONS

Search for information about different substances dissolved in natural water reservoirs. Compare the molar concentrations of the most important salts dissolved in oceans and seas. How could they be beneficial for man?

4. MOLARITIES IN THE EVERYDAY LIFE

Think about different solutions you often use. Find out their compositions and try to calculate the molar concentrations of the solutes (use the information on the products labels).