Moles Notes

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What is a mole?

A mole: of particles contains the same number of particles as there are atoms in exactly 12 g of carbon 12.

This number is **6.02×10^{23}** and is called **Avogadro's Number** or **Avogadro's constant**.

So, a mole tells us the exact number of atoms, ions or particles that we are working with in an experiment. It's a very accurate way of working with masses. Moles in chemistry have nothing to do with moles the animals 😊

Important note: if you are confident in finding the molecular mass (Mr), also known as the relative formula mass, for a substance then please do continue through this section. If you're not confident with this then **please stop here**. Go back and practise this until you are very confident with calculating Mr.

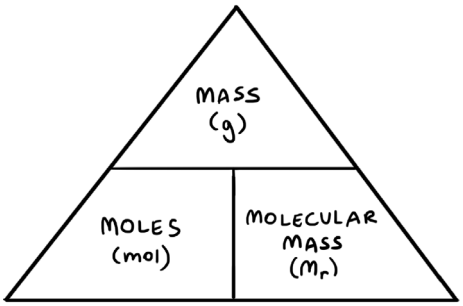
The mass of 1 mole of a substance is equal to its Relative Mass in grams.

What this means is that if you have 14 g of nitrogen atoms you would have 1 mole of nitrogen atoms.

23 g of sodium atoms = 1 mole of sodium atoms.

71 g of chlorine gas (Cl_2) = 1 mole of Chlorine gas.

How do we calculate moles? We use the following formula. Be aware of how to rearrange the formula to find each element within it.



$$mass = moles \times molecular\ mass$$

$$g = mol \times mr$$

$$\text{moles} = \frac{mass}{molecular\ mass}$$

Example 1: What is the mass of 0.75 moles of carbon?	**Example 2:** How many moles of carbon are there in 10g?
Mass = mol × Mr	Moles = mass ÷ Mr
Mass = 0.75 × 12	Moles = 10 ÷ 12
Mass = 9 g	Moles = 0.833 mol

Have a go 😊 Find the number of moles of the following masses. Give your answers to 3 significant figures. Show all working.

1. 48g of Li. **Mol:** ……

2. 97g of H_2O. **Mol:** ……

3. 240g of Na_2SO_4 **Mol:** ……

Answers: 1. = 6.86 2. = 5.38 3. = 1.69

Equations and Moles

A balanced chemical equation tells us about the number of moles reacting and being produced.
For example, in the combustion of methane below:

$$CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (g)$$

This equation tells us that **1 mole of methane** reacts **with 2 moles of oxygen** to give **1 mole of carbon dioxide** and **2 moles of water** vapour. The numbers are moles 😊

Exam questions involving moles and equations are typically carried out in **<u>four</u>** steps:

Step 1: Write a balanced equation for the reaction.
Step 2: Convert mass into moles.
Step 3: Use the equation to find the ratio of moles.
Step 4: Convert moles into a mass.

Example 1: What mass of water vapour is formed when 3.2 g of methane burns in oxygen?
Step 1: Write a balanced equation for the reaction. You may have to balance the equation, though the majority of questions are already balanced.

$$CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (g)$$

Step 2: Convert mass into moles.

Moles of CH_4 = mass ÷ Mr
Moles of CH_4 = 3.2 ÷ 16
Moles of CH_4 = 0.2 mol

Step 3: Use the equation to find the ratio of moles.
From the equation above we can see that 1 mole of methane gives 2 moles of water vapour.
So the ratio is 1 : 2.

So, 0.2 mol of methane gives 0.4 mol of water vapour.

Step 4: Convert moles into mass.

Mass of H_2O = mol × Mr
Mass of H_2O = 0.4 × 18
Mass of H_2O = 7.2 g

Example 2: Hydrogen sulfide reacts with oxygen gas to produce sulfur dioxide and water. What mass of sulfur dioxide can be made from 80 g of oxygen gas?

Step 1: Write a balanced equation for the reaction.

$$2H_2S\ (g) + 3O_2\ (g) \rightarrow 2SO_2\ (g) + 2H_2O\ (l)$$

Step 2: Convert mass into moles.

The Mr of O_2 = 2 × 16 = 32

Moles of O_2 = mass ÷ Mr
Moles of O_2 = 80 ÷ 32
Moles of O_2 = 2.5 mol

Step 3: Use the equation to find the ratio of moles.
From the equation we can see that 3 moles of O_2 gives 2 moles of SO_2.

2.5 ÷ 3 × 2 = 1.666 mols of SO_2.

Step 4: Convert moles into mass.

The Mr of SO_2 = 32 + 2(16) = 64

Mass of SO_2 = mol × Mr Mass of SO_2 = 1.666 × 64 **Mass of SO_2 = 106.67 g**

Limiting reactants

This scares quite a few students each year, but it's very straightforward. Let's put it like this…

Let's say you were baking a cake. You have 1000 g of flour, 50 eggs and 10 litres of milk. To make one cake we need to use 500 g of flour, 5 eggs and 2 litres of milk. How many cakes can we make?

Yes, we can make a maximum of 2 cakes. What was the thing that prevented us from making more? What reactant **limits us from making more product** 😊 Yes! It's the flour! We have more than enough eggs and milk to make more cakes but we will run out of flour after 2 cakes. So the flour is the limiting reactant in this example 😊

Limiting reactants: are reactants that get fully used up in a reaction so it **limits** the amount of product(s) which can be made.

What effect do limiting reactants have on the reaction? The limiting reactant limits how much product is formed.

Can we tell which reactant is the limiting reactant from the question? Depending on the question, yes 😊, if one reactant is described as being in excess, then this one is not the limiting reactant.

In excess: means that there is more of that reactant than you need to do the practical.

Questions on limiting reactants look and work very much like standard mole calculation questions. Let's look at some examples of questions involving limiting reactants.

Example 3: In a chemical reaction, 4 moles of reactant A react with 3 moles of reactant B to produce product C. If you start with 6 moles of A and 5 moles of B, which reactant is the limiting reactant?
Circle the letter of the correct answer.

A	B	C	D
Reactant A	Reactant B	Reactants A and B	Neither A or B

Correct answer: A is the correct answer.
Explanation: we notice the ratio from the question is 1 : 0.75 so 6 moles of reactant A would need 4.5 moles of reactant B to fully react. We have 5 mols of reactant B so it is in excess and reactant A is the limiting factor.

Example 4: A student reacts 25 grams of aluminium with 50 grams of sulfuric acid.
The equation for the reaction is:

$$2Al + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2$$

a. Calculate the number of moles of aluminium used in the reaction.

Moles of Al = mass ÷ Mr
Moles of Al = 25 ÷ 27 = 0.925 mols

b. Calculate the number of moles of sulfuric acid used in the reaction.

Moles of H_2SO_4 = mass ÷ Mr
Moles of H_2SO_4 = 50 ÷ 98
Moles of H_2SO_4 = 0.510 mols

c. Determine the limiting reactant in this reaction and give a reason for your answer.

We have 0.925 mols of Al. How many mols of H_2SO_4 will this react with?

Ratio of number of moles of aluminium to sulfuric acid is 2 : 3

Moles of H_2SO_4 that would be need to fully react with the Al =(0.925 ÷ 2) × 3

Moles of H_2SO_4 that would be need to fully react with the Al = 1.3875 mols

There is only 0.510 mol of H_2SO_4 present and we would need 1.3875 mols. So H_2SO_4 is the limiting reactant.

Moles and Gases

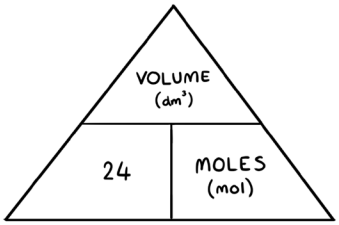
Questions on moles with gases come up here and there in exam papers. They are lovely, quick questions to get 😊 just learn the rule and the equation and you'll be fully set for questions on these.

The rule: <u>one mole of any gas occupies a volume of **24 decimetres cubed** (dm^3) or **24,000 centimetres cubed** (cm^3) at room temperature and pressure</u>.

1 decimetre cubed is equal to 1000 centimetres cubed

$1\ dm^3 = 1000\ cm^3$

The Equation



$$moles = \frac{volume\ (dm^3)}{24}$$

$$volume\ (dm^3) = moles\ \times 24$$

Let's look at a few examples 😊

Example 5: Find the number of moles of the following gases (measured at room temperature and pressure).

1. 72 dm^3 of oxygen (O_2). Moles $= \frac{volume\ (dm^3)}{24} = \frac{72}{24} = 3$ moles
2. 12 dm^3 of hydrogen (H_2) Moles $= \frac{volume\ (dm^3)}{24} = \frac{12}{24} = 0.5$ moles

Example 6: Find the volume of the following gases (measured at room temperature and pressure).

1. 6 moles of nitrogen gas (N_2). $volume\ (dm^3) = 6 \times 24 = 144\ dm^3$
2. 0.75 moles of ethane (C_2H_6). $volume\ (dm^3) = 0.75 \times 24 = 18\ dm^3$

Example 7: Find the mass of carbon dioxide formed when 750 cm^3 of propane reacts completely with oxygen.

The equation for the reaction is given below.

$$C_3H_8\,(g) + 5O_2\,(g) \rightarrow 3CO_2\,(g) + 4H_2O\,(l)$$

Stage 1: **find the number of moles of propane and use this to find the moles of CO_2.**

But first we must convert the cm^3 to dm^3. We do this by dividing 750 by 1000.

$$\text{Moles} = \frac{volume\ (dm^3)}{24} = \frac{0.750}{24} = 0.03125 \text{ moles}$$

The moles of propane are 0.03125

The ratio of C_3H_8 to CO_2 is 1 : 3

We must multiply 0.03125 by 3 to find the moles of CO_2.

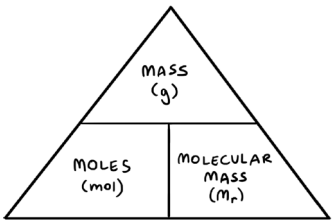
Moles of $CO_2 = 0.03125 \times 3$

Moles of $CO_2 = 0.09375$ mols

Stage 2: **use the mole equation to find the mass from the moles.**

Mass = mol × Mr

Mass = 0.09375 × 44

Mass = 4.125 g

The mass of CO_2 formed is **4.125 g**