DIY molecular models

Until recently it has been completely impossible to 'see' a molecule. Realistically speaking, it still is - for most people, most of the time. So, in order to try to visualise what is happening, we need to use models. Models give us the best and most direct view of the molecular world. Modelling is also an excellent tool for learning about chemical theory, be it atomic structure, Lewis acids/bases or conjugated systems.

Figure 1 *- A 'mole' of water.*

Most modelling is nowadays carried out on computers using software to create virtual images. The professional versions of these are expensive but there are various free, open source versions that are more than good enough for school use such as Chemsketch or JMol.

There is still much to be said, however, for using 'real world' molecular models, especially with younger students: the physical interaction with the models helps to cement understanding.

It is possibly to buy molecular model sets quite easily and, on an individual basis these are not too expensive but when it comes to a class set, things become more difficult to afford - particularly these days. There are, however, cheap yet effective alternatives: one of these is to use plasticine.

The 'atoms' can be simply created by rolling balls of plasticine - the variety of colours can be used to represent different types of atoms just as in 'real' molecular modelling kits. Plasticine has the advantage of being slightly tacky to the touch so the 'atoms' will stick together without the need for any reinforcement. If this is required (for larger structures perhaps) then cocktail sticks make excellent 'bonds'. Students can thus easily make their own models and assemble/disassemble them to enhance their understanding.

Here are a few simple modelling activities that can be used to assist the teaching of otherwise dry, theoretical concepts.

Key

Hydrogen = White
Carbon = Black
Oxygen = Red/pink

The mole concept

The idea of the mole is absolutely central to chemistry but it can be a little hard for younger students to grasp.

Students make 2 sets of 4 (or 6 or 8) models of H_2O molecules (or any other simple molecule). You simply need to choose what number is going to stand in for Avogadro's number.

This set of 4 molecular models represents a mole.

This will help students have a visual aid and also be able to count the number of pieces to answer related questions, such as:

(i) how many molecules of H_2O are there in 1, 1.5, or 2 moles of H_2O?
(ii) how many moles of H_2O are there if you have 6, 7, or 8 molecules of H_2O?
(iii) how many atoms of hydrogen are there in 0.5, 1, or 2 moles of H_2O?

Figure 2 *- Molar mass.*

Methane and oxygen.

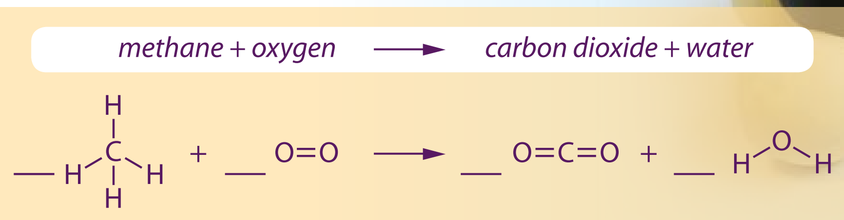

Figure 3 *- The unbalanced chemical equation and the structural formulae.*

Molar mass

The mass of a set of 4 molecules (1 mole) is measured. This represents the molar mass of the chemical substance. This does require making 'atoms' of a fairly consistent mass - a minor pain but not beyond reasonable achievability.

It is going to be difficult to get your 'molecules' exactly the right mass. The best option is to ensure they are **slightly** over the target weight and instruct the students to ignore anything after the decimal point (ideally mask the digits after the point with tape as shown in Figure 2).

Then a different number of 4-packed or any combination of 4-packed and individual molecular models, are weighed and tabulated.

It should soon become clear that a certain mass of a substance equals a set number of moles and vice-versa. Once the students seem happy with that idea then it should be relatively straightforward to explain that in 'real life' we simply replace 4 (or 6 or whatever your 'mole number' was) with Avogadro's number.

Balancing chemical equations

To help students to conceptualize the basic principles of balancing chemical equations a simple unbalanced chemical equation such as shown in Figure 3 is used. To help students, you may want to include the structural formulae as well.

Each group of students makes CH_4 and O_2 models.

Students start with only 1 model of CH_4 and 1 of O_2 to make models of CO_2 and H_2O.

After 2 H_2O molecular models are constructed using parts from the CH_4 and O_2 models, students realize that there are not enough oxygen atoms to make the CO_2 model. (or they construct the CO_2 molecule and have none left for the H_2O).

At this point, they are allowed to use another O_2 model as long as they record the number of each model they use in a table such as the one below. With the 1 carbon atom left and the 2nd O_2 model they are able to make a model of CO_2.

1 x CH_4 and 1 x O_2 | **Disassembled** | **2 x H_2O with 1 x C left over**

Add more O_2 | **The products 2 x H_2O and 1 x CO_2** | **The reaction $CH_4 + 2O_2 = CO_2 + 2H_2O$**

Figure 4 *- Reactants and products.*

Number of reactants and products

Now, the students should be able to balance the chemical equation by writing the number of each model used or made in front of its corresponding molecule in the unbalanced equation:

To enforce the balancing concept, students can place 1 model of CH_4 and 2 models of O_2 on one side of their desk or work bench and 1 model of CO_2 and 2 models of H_2O on the other side and count number of coloured pieces on each. They should have the same number of black, white, and red/pink pieces on both sides (Figure 4).

Limiting reactant concept

The molecular models can be used to demonstrate limiting reactant concept. The approach is very similar to balancing equations. Students are given a certain number of each type of reactant molecule and are asked to make the products. Soon they will realize that there will be some leftover of one of the reactants.

As happened in the example above - in the initial conditions, there is not enough oxygen so therefore the oxygen is the limiting factor.

Conservation of mass

To emphasize the importance of balancing chemical equations and demonstrating the law of conservation of mass, students measure the mass of 1 model of CH_4 along with 1 O_2, and 1 molecular model of CO_2 and 1 H_2O together.

The sensible thing is to weigh their CO_2 and H_2O products first and then dismantle them to re-form the CH_4 and O_2 which they weigh again. (That avoids the possibility of different 'molecules' not weighing the same).

Next, they weigh CH_4 and O_2 together and CO_2 and H_2O together.

Finally, they weigh the correct number of each model as indicated in the balanced chemical equation and not that this time, with a balanced equation, the mass is the same for both sides of the equation.

Students can repeat these procedures using other unbalanced chemical equations.

Isomers

It is quite simple to use models like this to illustrate isomerism.

Geometrical isomers - It is easy to show that a single bond allows for easy rotation around it so the arrangement of the atoms around the (black) carbon atom makes no difference.

But a double bond shows that it is impossible (unless students get silly!) to rotate between the cis and trans forms as shown below (Figure 5).

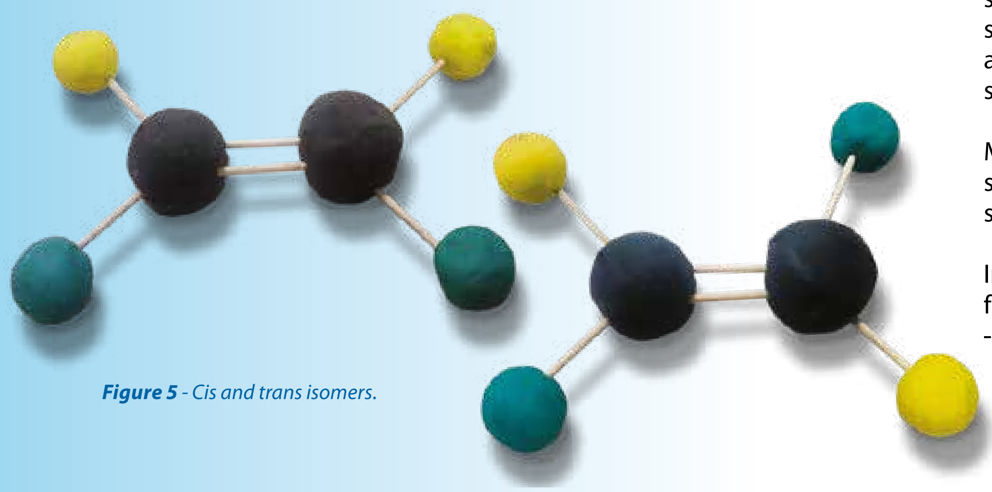

Figure 5 *- Cis and trans isomers.*

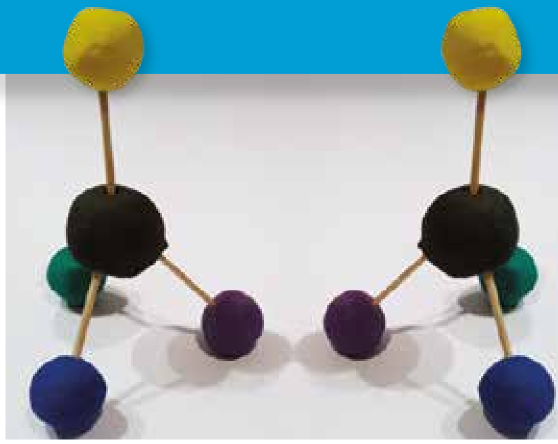

Figure 6 *- Stereoisomerism.*

You can also use your molecular models to illustrate stereoisomerism and the idea that mirror images are non-superimposable.

If you have enough colours, it is possible to create a chiral molecule with 4 different groups and the students will be able to see that if they make 2 molecules that are mirror images of each other then they cannot superimpose them one on the other.

You could then redefine the coloured balls to represent functional groups of a genuine chemical with stereoisomers.

For instance, using the same balls above, you can represent lactic acid if:
Black = a carbon atom
Yellow = a hydrogen atom
Blue = a carboxyl group
Purple = a hydroxyl group
Green = a methyl group

Edible alternatives

Similar models can be made using 'midget gem' sweets. These won't adhere to each other easily but cocktail sticks work well. There is here the added advantage that students can be allowed to eat any successful equations (as long as this activity is undertaken is suitable surroundings i.e. not in a lab).

Marshmallows and cocktail sticks can be used to make very satisfactory ionic lattices.

In fact there are endless possibilities for you and your classes to explore - happy modelling!