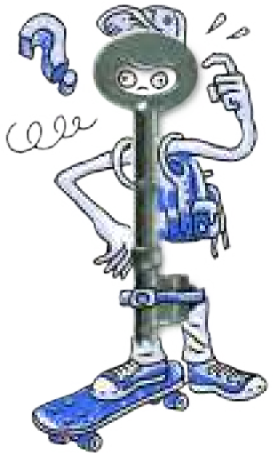
2 Chemical reactions



KEY QUESTIONS:

- What is a chemical reaction?
- How can we represent what happens in a chemical reaction?
- What do the different symbols in a chemical reaction equation mean?
- What do the numbers in a chemical reaction mean?
- What does it mean to balance a chemical equation?
- How can we tell if a reaction is balanced?
- How do we translate between word equations, picture equations and chemical equations?

NEW WORDS

- bond
- reactant
- product
- chemical reaction
- macroscopic
- submicroscopic
- symbolic

In Gr. 8 Matter and Materials we learnt about **chemical reactions** for the first time. Can you remember the main ideas about chemical reactions? Here they are again:

- During chemical reactions, materials are changed into new materials with new chemical and physical properties.
- The materials we start with are called **reactants**, and the new materials that form are called **products**.
- During a chemical reaction, atoms are rearranged. This requires that bonds are broken in the reactants and new bonds are formed in the products.

In this chapter we are going to build on these ideas. We will focus on two things:

1. how to write chemical reaction equations; and
2. how to balance chemical reaction equations.

This will prepare us for the chapters that follow this one, in which we will be looking at different types of chemical reactions.

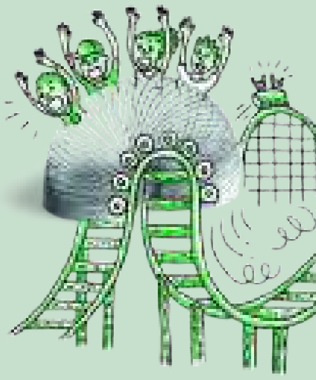
Before we get to chemical reactions, however, it is important that we remind ourselves of the different ways that we have been thinking about chemical compounds up to now. The next section will show how they all fit together.

2.1 Thinking about chemical reactions

Scientists learn to think about compounds on three different levels:

- macroscopic
- microscopic
- submicroscopic

As a young scientist, you have already been introduced to this kind of thinking. The three levels can also be thought of as three different ways to represent compounds. The next activity will help you understand what this means.

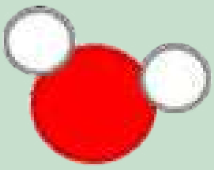


ACTIVITY: Drawing water

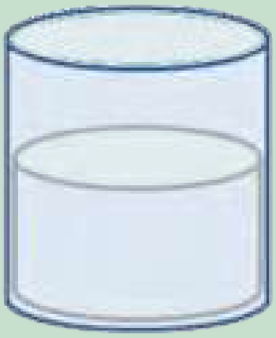
INSTRUCTIONS:

The instruction for this activity is really simple: Draw a picture of water. You may use the space below for your drawing.

Your drawing may look like one of the diagrams below. They all represent water. But which one is correct?



(i)



(ii)

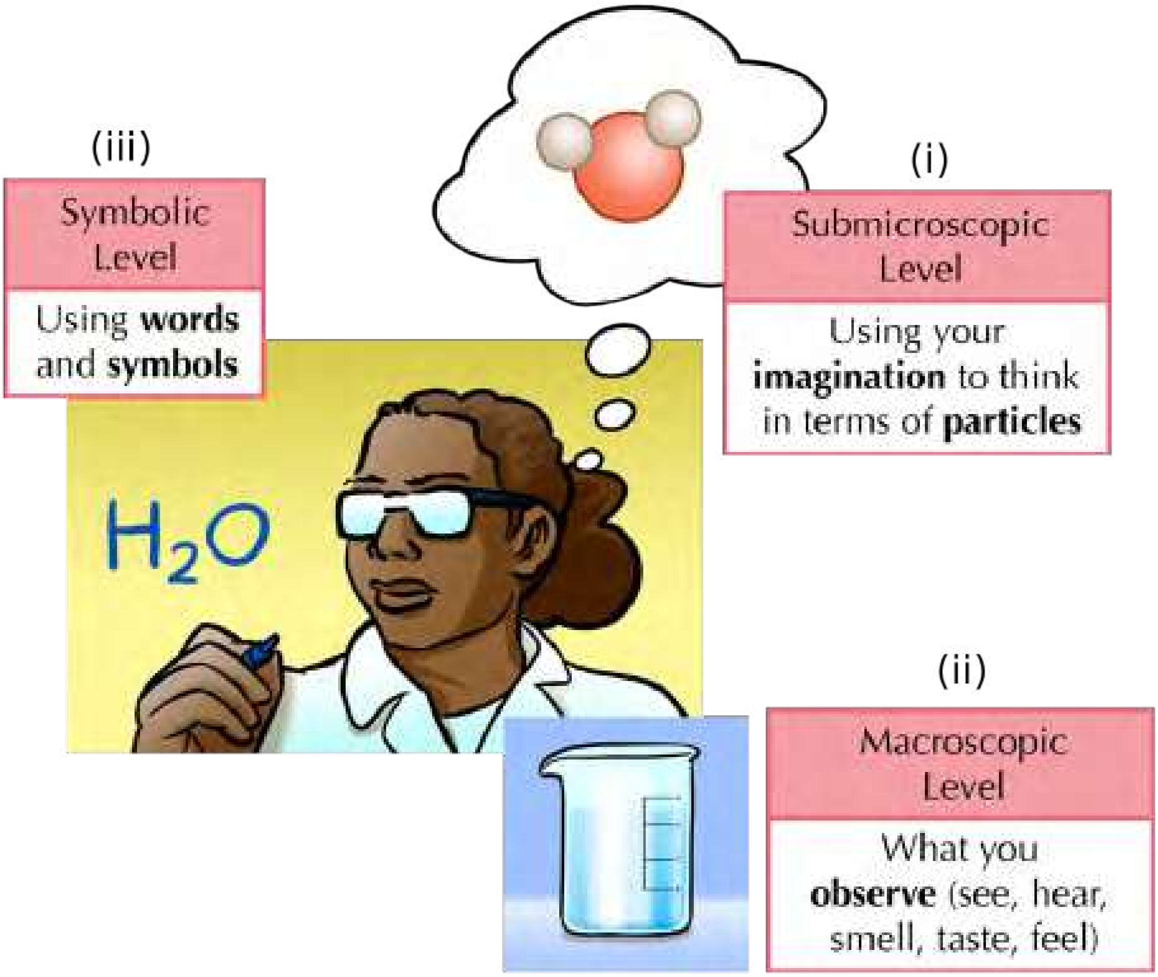
H_2O

(iii)

They are all correct!

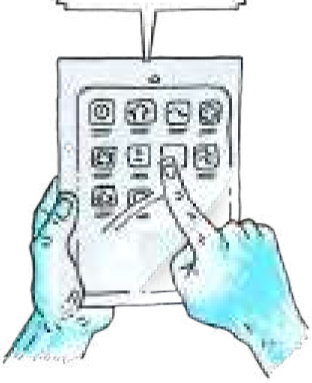
The three diagrams above all represent water, but they are very different from each other. We say that they are three different **representations** of the same thing, namely water.

The following diagram shows how the three representations fit together.



TAKE NOTE

Submicroscopic means 'smaller than microscopic', or 'too small to see through a microscope'. Sometimes it helps to think that this is what we would see if we had special 'submicroscopic goggles' on to 'see' at the atomic level!



The water molecule in the top right shows what a particle of water would look like (i). We cannot see water particles with our eyes, therefore we have to imagine them. This is why the water molecule is inside a thought bubble. We call this a **submicroscopic representation**.

VISIT

Find out about special microscopes which enable people to 'see' atoms

bit.ly/19YIOCU

The beaker of water shows what water looks like to our eyes (ii). We call this a **macroscopic representation**, because it is observable. That means it can be observed by using our senses such as seeing, feeling, hearing, tasting or touching.

The chemical formula on the left uses chemical symbols to represent water (iii). We have learnt that chemical formulae are made up of element symbols. We can think of chemical symbols and formulae as a chemical 'language', because they tell a story. The 'story' told by the formula H_2O is that a water molecule consists of two atoms of H and one atom of O. The formula 'H_2O' is a **symbolic representation**.

Experienced scientists can move easily between these three levels. They can translate the symbolic language of chemical formulae to submicroscopic pictures in their mind. This is what we will practice in this chapter.

Before moving on, try another example where you draw the 3 different levels of carbon dioxide in the space below. Label each level.

VISIT

The world's smallest movie made with atoms bit.ly/168BHFa and how the scientists made it

bit.ly/1cYU80s

2.2 How do we represent chemical reactions?

How would you define a chemical reaction? Write down some of your ideas. The following words may help you formulate your sentences.

reactants, products, bonds, rearranged, atoms, molecules, new compounds

NEW WORDS

- chemical equation
- coefficient
- subscript

A chemical reaction is a rearrangement of atoms in which one or more compounds are changed into new compounds.

All chemical reactions can be represented by equations and models. To some people, chemical equations may seem very hard to understand. Since atoms and molecules can not be seen they have to be imagined and that can be quite difficult! Luckily, we have had some preparation because we have been drawing molecules since Gr. 7.

Anytime that atoms separate from each other and recombine into different combinations of atoms, we say a chemical reaction has occurred. No atoms are lost or gained, they are simply rearranged.

1. Word equations

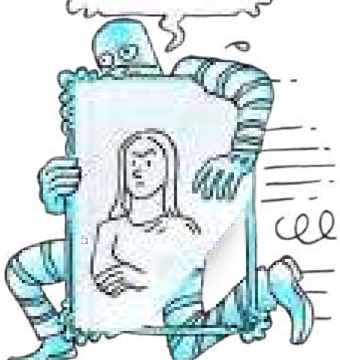
When we represent a chemical reaction in terms of words, we write a **word equation**. For example, when hydrogen gas reacts with oxygen gas to form water, we can write a word equation for the reaction as follows:

hydrogen + oxygen $\rightarrow$ **water**

To the left of the arrow, we have the 'before' situation. This side represents the substances we have before the reaction takes place. They are called the **reactants**. What are the reactants of this reaction?

TAKE NOTE

In mathematic equations we use an equal sign (=) for example 2 + 2 = 4, but in scientific chemical equations, we use an arrow ($\rightarrow$), for example $C + O_2 \rightarrow CO_2$.



To the right of the arrow we have the 'after' situation. This sides represents the substances that we have after the reaction has taken place. They are called the **products**. What is the product of this reaction?

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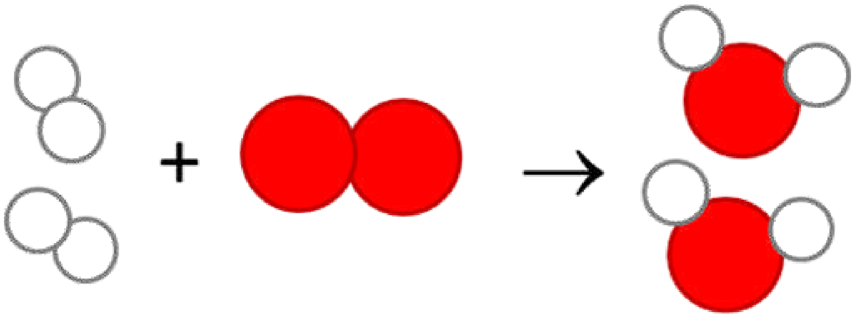
2. Picture equations

The same reaction of hydrogen reacting with oxygen, can also be represented in pictures called submicroscopic diagrams. The diagram below shows that the atoms in two hydrogen molecules (H_2) and one oxygen molecule (O_2) on the left rearrange to form the two water molecules (H_2O) on the right of the arrow. Hydrogen atoms are white circles and oxygen atoms are red circles.

What kind of representation is this: macroscopic, submicroscopic, or symbolic?



Now we are going to convert our submicroscopic picture to a symbolic one:

What is the product of the above reaction? What are the reactants of the above reaction? Write their formulae.

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3. Chemical equations

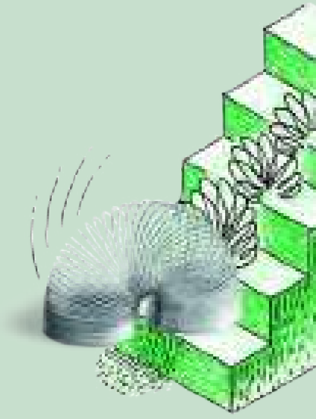
When we represent a chemical reaction in terms of chemical formulae (symbols), it is called a **chemical equation**. The chemical equation for the above reaction would be as follows:

$$2\,H_2 + O_2 \rightarrow 2\,H_2O$$

What kind of representation is this: macroscopic, submicroscopic, or symbolic?

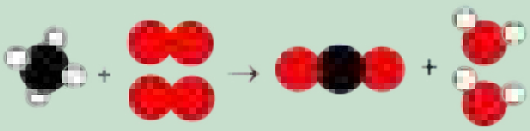
We still have reactants on the left and products on the right.

ACTIVITY: Identifying the different types of equations



INSTRUCTIONS:

1. Complete the following table by identifying the different types of equations which have been shown, namely word, picture or chemical equations.

Equation	**Type of equation**
	
carbon dioxide + water → glucose + oxygen	
$Fe + O_2 \rightarrow Fe_2O_3$	
	
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$	

QUESTIONS:

1. What process does the equation, carbon dioxide + water → glucose + oxygen, represent?

2. What process does the equation, $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$, represent?

When you look at the reaction equation above you will notice two kinds of numbers:

- Numbers *in front of* chemical formulae in the equation. They are called **coefficients**.
- Smaller numbers used *inside and below* the chemical formulae. These are called **subscripts**.

Coefficients and subscripts mean different things, as you will see in the next section.

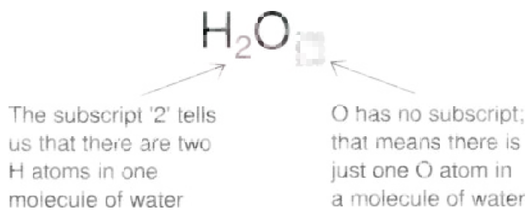
Coefficients and subscripts in chemical equations

Why is there a '2' in front of the formula for water (H_2O) in the chemical equation for water? This is because two molecules of H_2O can be made from two molecules of H_2 and one molecule of O_2 in our reaction.

The numbers in front of the formulae in the chemical equation are called **coefficients**. They represent the numbers of individual molecules that are in the chemical reaction.

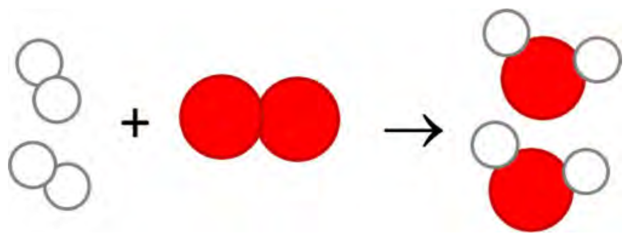
You will notice that O_2 does not have a coefficient in the reaction above. When there is no coefficient, it means that just one molecule of that substance takes part in the reaction.

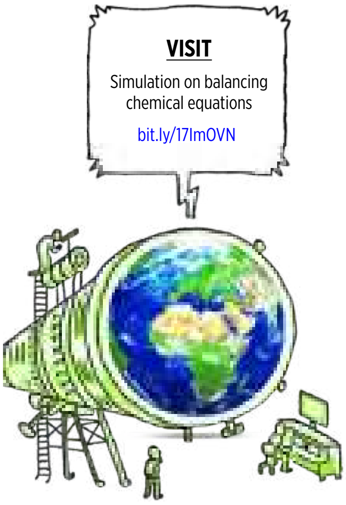
In the previous chapter, we learnt how to interpret chemical formulae. When we read the formula, the **subscripts** tell us how many atoms of a particular element are in one molecule of that compound.



2.3 Balanced equations

Now we are going to learn what it means when a reaction is **balanced**. Here is our submicroscopic picture again.



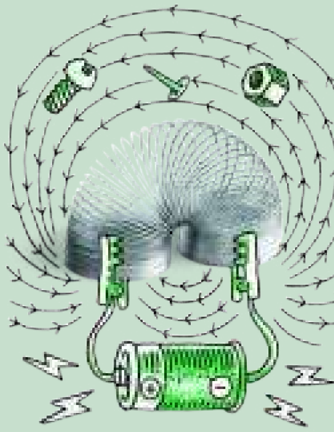


Count how many H atoms are on the left side of the reaction. How many on the right?

Count how many O atoms are on the left side of the reaction. How many on the right?

Did you notice that the numbers and types of atoms are the same on the left and on the right of the reaction? The reactants have four H atoms and two O atoms. The products have four H atoms and two O atoms.

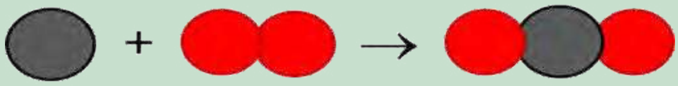
When this is true of a reaction equation, we say the equation is **balanced**.



ACTIVITY: When is a reaction balanced?

INSTRUCTIONS:

1. Study the equation below. The black atoms are carbon (C), and the red atoms are oxygen (O). They will not always necessarily be this colour - this is just a representation.
2. Answer the questions that follow.



QUESTIONS:

1. What kind of representation is this: macroscopic, submicroscopic or symbolic?

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2. Write a symbolic representation (a chemical equation) for the above reaction.

___

3. Write the formulae for the reactants of this reaction.

___

4. Write the formula for the product of the reaction.

___

5. Count how many C atoms are on the left side of the reaction. How many on the right?

___

6. Count how many O atoms are on the left side of the reaction. How many on the right?

___

7. Is the reaction balanced? Why do you say so?

___

___

Now that we know how to recognise a balanced equation, we are going to learn how to balance them!

What is a balanced equation? Write down your own definition.

___

___

We are going to use a few examples of real reactions to learn how to balance equations. In the chapters following this one, we are going to see what these reactions look like in real life, but for now, we will just focus on how to balance equations.

ACTIVITY: Magnesium burning in oxygen

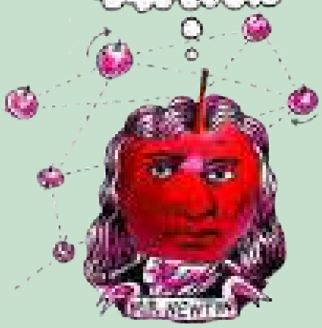
When magnesium metal burns in oxygen, we can write the following word equation for the reaction that occurs between these two elements:

magnesium + oxygen → magnesium oxide

Magnesium flakes burning in oxygen in a sparkler.

DID YOU KNOW?

Magnesium flakes are often used in some fireworks, such as sparklers, because when they burn they create the bright, shimmering sparks.



QUESTIONS:

1. What are the reactants of the reaction?

___

2. What is the product?

___

We can change the word equation into a chemical equation:

$Mg + O_2 \rightarrow MgO$

3. What kind of representation is this: macroscopic, submicroscopic, or symbolic?

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4. Is the equation balanced? If you are not sure, count the number of each type of atom on the left, and on the right. Perhaps it will help to look at a submicroscopic representation (a particle diagram) of the reaction:

You can write your results in the table below:

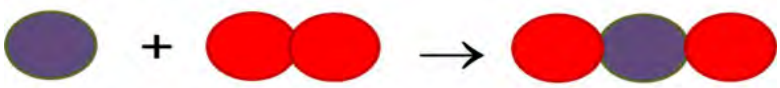
Number of atoms	Reactants	Products
Mg		
O		

5. What is your conclusion: Is the equation balanced? Explain your answer.

So how could we balance the equation to describe magnesium burning in oxygen? When balancing reactions, there is one simple rule:

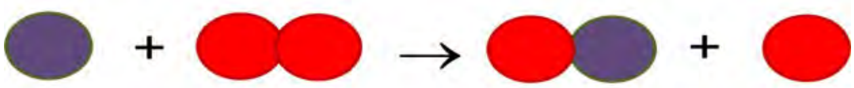
You may only add compounds that are already in the equation. This means only coefficients may be changed, not subscripts!

Let's try a few alternative solutions. Would it help to add an O atom on the right, like this?

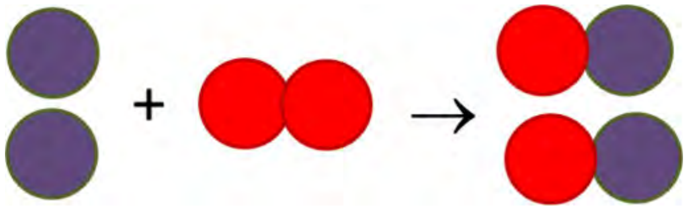


Now the O atoms are balanced on both sides of the equation, but we don't have MgO on the right anymore. We have changed the formula on the right to MgO_2. That means we have changed a subscript in the formula. You cannot change the formula of a compound when balancing chemical equations.

Adding single atoms to any side of the equation is also not allowed. That means the following equation is also not correct:



Remember that we may only use the chemical formulae that are already in the equation. We need two MgO's on the right to balance the two O's in O_2. We also need two Mg's on the left to balance the two MgO's on the right.



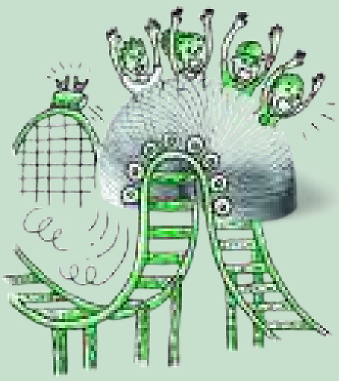
Can you build this equation with play dough balls or beads? When you convert the play dough 'reactants' to 'products', are there any unused 'atoms' left behind afterwards?

Now, let us take this a step further. We are going to convert our balanced submicroscopic equation to a symbolic chemical equation. Write down a balanced equation for magnesium burning in oxygen to produce magnesium oxide.

Here are a few important rules for balancing chemical equations:

- When we balance reaction equations we may ONLY add coefficients to the chemical formulae that are already in the equation.
- We may NOT change the chemical formulae of any of the reactants or products by changing the subscripts in a formula.
- We may NOT add other reactants or products. This includes adding single atoms of any of the elements already in the reaction equation.
- We may NOT remove reactants or products.

We are now ready to practice balancing other reaction equations.



ACTIVITY: Iron reacts with oxygen

When iron rusts, it is because the iron metal reacts with oxygen in the air to form iron oxide.

An old car with rust on the bonnet.

A closeup photo of a rusted barrel.

The word equation is the following:

iron + oxygen → iron oxide

The chemical equation is the following:

$Fe + O_2 \rightarrow Fe_2O_3$

Is the equation balanced? Draw a submicroscopic picture to help you decide.

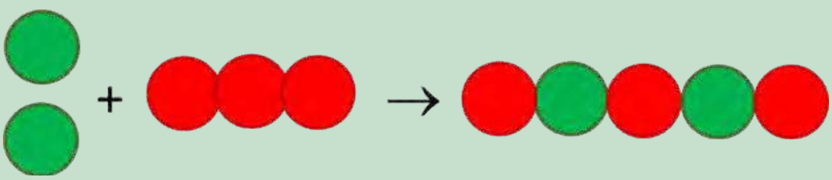
You could also use a table like the one below:

Number of atoms	**Reactants**	**Products**
Fe		
O		

What is your verdict: Is the equation balanced? Explain your answer.

How could we balance the reaction? Three possibilities (Plans A, B and C) are given below. You must evaluate each plan, and say if it is allowed or not.

Plan A



Changes made	Is this change allowed? Yes/no?	Reason
Add one Fe atom on the reactant side.		
Change O_2 to O_3 on the reactant side of the equation.		

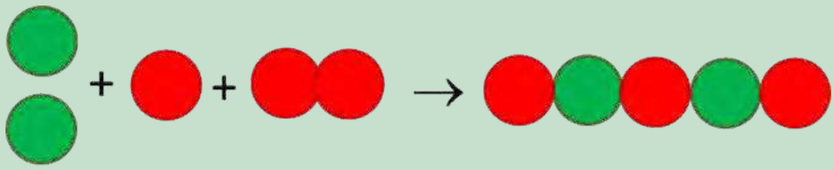
1. Convert the picture equation above to a chemical equation.

2. Did any coefficients change? Remember that this is allowed.

3. Did any formulae change, or were any new formulae added? Remember that this is NOT allowed.

4. What do you think: Can this plan work? Explain your answer.

Plan B



Changes made	Is this change allowed? Yes/no?	Reason
Add one Fe atom on the reactant side.		
Add one O atom on the reactant side.		

1. Convert the picture equation to a chemical equation.

2. Did any coefficients change? Remember that this is allowed.

3. Did any formulae change, or were any new formulae added? Remember that this is NOT allowed.