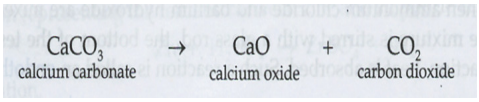
Chemical reactions: The processes in which a substance or substances undergo to produce new substances with new properties are known as **chemical reactions.** For example, when calcium carbonate is heated, calcium oxide (lime) and carbon dioxide are formed. $CaCO_3 \longrightarrow CaO + CO_2$

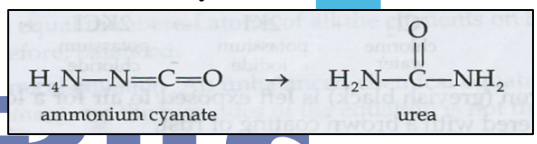
The breaking up of calcium carbonate into calcium oxide and carbon dioxide is, thus, a chemical reaction because calcium carbonate changes into substances calcium oxide and carbon dioxide.

Reactant: The substance which takes part in a chemical reaction is called reactant. For example, in the breaking up of calcium carbonate into calcium oxide and carbon dioxide, calcium carbonate is the reactant. Similarly, sodium and water are the reactants when they react to form sodium hydroxide and hydrogen gas. $Na + H_2O \longrightarrow NaOH + H_2$

Product: A product is a new substance formed in a chemical reaction. For example, hydrogen and sodium hydroxide are the products of the reaction between sodium and water. Similarly, in the breaking up of calcium carbonate, calcium oxide and carbon dioxide are the products.



You know, atoms in a molecule are held together by a force of attraction called bond. The molecules do not participate directly in a chemical reaction. First they break down into atoms and these atoms then take part in the reaction. New bonds are formed between the atoms to form the products. That is, there take place rearrangements or regroupings of atoms in various ways to give products. For example, when ammonium cyanate is heated, different bonds in ammonium cyanate molecules are broken and new bonds are formed to produce urea. Here, we see that the molecular formulae of both ammonium cyanate and urea are the same, but their properties are quite different and they are two different compounds. Such compounds are known as isomers of each other and the reactions that produce such isomers are called isomerization reactions.



Equation: atoms in a molecule are held together by a force of attraction called bond. The molecules do not participate directly in a chemical reaction. First they break down into atoms and these atoms then take part in the reaction. New bonds are formed between the atoms to form the products. There takes place the rearrangements or regrouping of atoms in various ways to give products. For example,

Types of Changes:

1. Physical Change: it is a type of change in which the matter is altered but no new substance is formed. For example: tearing of paper.

2. Chemical Change: it is a type of change in which some bonds are broken or formed giving a different ending product. For example: rusting of iron.

Consider the following changes occurring in daily life:

- Souring of milk left at room temperature during summers.
- Rusting of iron tawa exposed to humid air.
- Fermentation of grape juice.
- Digestion of food.
- Respiration (taking in oxygen and giving out carbon dioxide)

Q: What does hydrated iron (Ill) oxide mean? Hydrated iron (HI) oxide means that water molecules are loosely attached to iron (Ill) oxide molecule, they are not chemically bonded to it.

ABHYAS Academy, Behind Pragat Shiv Mandir, Near Govt. College, Nishat Cinema Road, Ambala Cantt.
Ph No. +91-171-2631595, 9416541198, e-Mail: anusethi1968@yahoo.com Website: www. abhyasonline.in

Q: Why all the above changes are chemical changes? When milk is kept at room temperature during summers it becomes sour. In summer the temperature is high, it is favorable for the growth of micro organisms. So when the milk is kept at room temperature the micro organisms present in the milk grow. The enzymes present in these micro organisms convert milk sugar (lactose) to lactic acid.

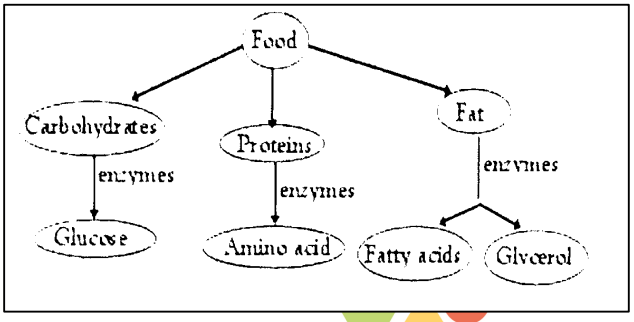
• When iron tawa is exposed to humid air, iron reacts with water and oxygen to form rust. Rust is hydrated iron (III) oxide.

Iron + H_2O + O_2 ⟶ Hydrated iron oxide (Rust)

• When grape juice is fermented, sugar present in the juice gets converted into alcohol. This reaction also takes place in the presence of enzymes.

Sugar ⟶ alcohol

• When food is digested, the complex nutrients of the food are broken down into simpler substances in the presence of enzymes. The main nutrients present in the food are carbohydrates, proteins and fats. End product(s) of the digestion of carbohydrates is glucose, of proteins is amino acid, and of fats are fatty acids and glycerol.



• **Exercise**:

Q: Why digestion of food is a chemical change?

Q: Why is the melting of ice not a chemical change?

Q: Physical changes may or may not be permanent. Name one physical change which is permanent.

Q: Which of the following involves a chemical change?

a. Cutting of trees b. making of a pot c. Making tea

Burning of magnesium ribbon in air:

1. Take a magnesium ribbon.
2. Clean it with a sand paper. At room temperature, magnesium reacts with oxygen in the air to form magnesium oxide. This magnesium oxide forms a layer over magnesium metal and protects the metal. Before burning the magnesium ribbon, this layer of magnesium oxide has to be removed. Hence it is cleaned with sand paper.
3. On burning magnesium ribbon in air, it burns with a dazzling white flame and changes into a white powder. This powder is magnesium oxide. Magnesium oxide can be collected in form of white powder

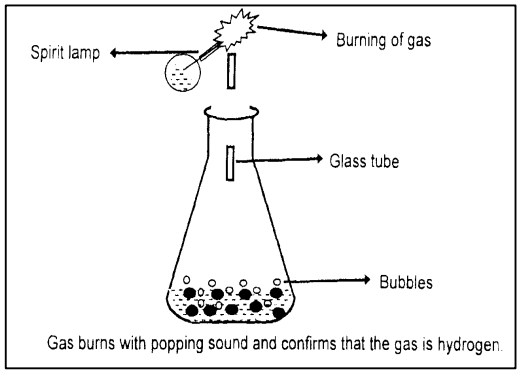
Magnesium + Oxygen ⟶ Magnesium oxide
(Solid) (gas) (solid)

In this reaction lot of heat and light is produced. During chemical reaction, energy changes take place.

Reaction of lead nitrate solution and potassium iodide solution

Take lead nitrate solution in a test tube and potassium iodide solution in the other. Both lead nitrate and potassium iodide solutions are white in colour. On mixing these two, a colourless potassium nitrate solution and yellow precipitate of lead iodide are formed. In this reaction both the reactants were white solutions and one of the products is colourless solution and other is yellow solid. During a chemical reaction change in colour and change in state takes place.

Lead nitrate (white solution) + Potassiumiodide (white solution) → Potassiumnitrate (colorlesssolution) + Lead iodide ↓ (yellow solid)



Gas burns with popping sound and confirms that the gas is hydrogen.

Only two gases produce so many bubbles: carbon dioxide and hydrogen.
Hydrogen is highly combustible and burns with a popping sound. To confirm whether the gas produced is hydrogen or not, bring a burning spirit lamp near mouth of glass tube.
Q: Why hydrogen burns with a popping sound? Because it reacts explosively with the oxygen of air.
Zinc reacted with dilute sulphuric acid to produce zinc sulphate and hydrogen gas. The flask becomes hot due to the production of heat during the reaction.

Zinc + Sulphuric acid ⟶ Zinc sulphate + hydrogen
(solid) (aqueous) (aqueous) (gas)

In this reaction gas was evolved and heat was given out. **During the chemical reaction change in temperature and evolution of a gas takes place.**
Zinc reacts with dilute hydrochloric acid in the same way.

Zinc + hydrochloric acid ⟶ Zinc chloride + hydrogen
(Solid) (aqueous) (aqueous) (gas)

All reactive metals react with dilute sulphuric acid and dilute hydrochloric acid in same way.
Characteristics of Chemical Reactions: There are some characteristics by which we can identify the occurrence of a chemical reaction. These are described below.
1. <u>Evolution of gas</u>: Some of the chemical reactions occur with the evolution of a gas or a mixture of gases. For example,
a) Metals like zinc, magnesium, iron etc react with dilute hydrochloric acid with the evolution of hydrogen gas.
b) When lead nitrate is heated, it gets decomposed to give a solid residue of lead monoxide with the evolution of nitrogen dioxide and oxygen gases.
2. <u>Formation of precipitate</u>: Sometimes, when two solutions are mixed together, a solid gets separated from the solution. The solid thus separated is called the precipitate. Example :
a) When an aqueous solution of sodium sulphate is mixed with a solution of barium chloride, a white precipitate of barium sulphate is produced.
b) When the aqueous solutions of lead acetate and potassium iodide are mixed, a yellow precipitate of lead iodide is produced.
3. Change in temperature: There are several reactions which occur with change in temperature. Example:
a) When quicklime (calcium oxide) is treated with water in a beaker, a large quantity of heat is produced. As a result, the beaker becomes **very hot.** Such reactions in which **heat is produced** are called **exothermic reactions.**
b) When ammonium chloride and barium hydroxide are mixed together in a test tube and the mixture is stirred with a glass rod, the bottom of the test tube **becomes cold**. In this reaction, **heat is absorbed**. Such reaction is called **endothermic reaction.**
4. Change in colour: In some chemical reactions, a change in colour is observed. **Example:**
a) When chlorine water (yellowish) is added to a solution of potassium iodide (colourless), a brown solution is obtained.
b) When iron (grayish black) is left exposed to air for a long lime, the outer surface of iron gets covered with a brown coating of rust.

5. Physical state: In some reactions, the physical state of the product becomes different from that of the reactant. For example, during the burning of a candle (solid), water vapors and carbon dioxide are produced which are gaseous. One or more of the above characteristics can certify that a chemical reaction is occurring. All chemical reactions are represented by chemical equations. A **chemical equation** is a short hand representation of a chemical reaction using the symbols and formulae of substances involved in the chemical reaction. The symbols and formulae of the substances (elements or compounds) are arranged to show the reactants and products of a chemical reaction.

Representation of chemical reaction: A chemical reaction can be described using a word equation. For example, when magnesium ribbon is burnt in oxygen, it gets converted into magnesium oxide. The word equation for this reaction is:—

Magnesium + Oxygen $\longrightarrow$ Magnesium oxide

Rules for writing chemical equation

Certain rules have to be followed while writing a chemical equation

1) The reactants taking part in the reaction and written in terms of their symbols or molecular formulae on the left-hand side of the equation.

2) A plus (+) sign is added between the formulae of the reactants.

3) The products of reaction are written in terms of their symbols or molecular formulae on the right- hand side of the equation.

4) A plus (+) sing is added between the formulae of the products.

5) In between the reactants and the products an arrow sign (→) is inserted to show which way the reaction is occurring.

Balanced and unbalanced chemical equation

1. Balanced chemical equation: A balanced chemical equation is one which contains an equal number of atoms of each element on both sides of the equation.

2. **Unbalanced chemical equation**: An unbalanced chemical equation is one in which the number of atoms of the elements on the two sides of the equation is not the same.

Writing a Chemical Equation: Chemical equations can be made more concise and useful if we use chemical formulae of reactants and products instead of words.

Consider the reaction of sodium with oxygen to form sodium oxide:

• Word equation for the reaction of sodium with oxygen to form sodium oxide is:— Sodium + Oxygen $\longrightarrow$ Sodium oxide

• This equation can be made more concise by writing the molecular formulae of the reactants and products. $Na + O_2 \longrightarrow Na_2O$ (more concise form)

• In this equation, the numbers of atoms of each element are not same on both the sides' i.e this equation is unbalanced and is called skeletal equation.

Mass of one sodium atom = 23u

Mass of one oxygen atom 16u

Total mass on left hand side (23 + (16 x 2)1 u = 55u

Element	Number of atoms on L.H.S.	Number of atoms on R.H.S.
Sodium	1	2
Oxygen	2	1

Total mass on right hand side 46u + 16u = 62u

But we have studied that during a chemical reaction, mass is neither created nor destroyed. Hence, the number of atoms of each element has to be equal on both the sides. Thus, the chemical equation needs to be balanced so that it confirms the Law of Conservation of mass.

Q: What would be the balanced chemical equation for reaction between sodium and oxygen?

Skeletal Equation: A skeletal equation is an equation in which various reactants and products are represented by their respective formulae but no attempt is made to equalize the number of atoms of various elements on both the sides of the equation.

Q: Which of the following chemical equation does not need to be balanced?

(a) $Zn + O_2 \rightarrow ZnO$ (b) $H_2 + O_2 \rightarrow H_2O$ (c) $HCl + NaOH \rightarrow NaCl + H_2O$

Rules for balancing a chemical equation:

1. To balance a chemical equation, draw boxes around each formula. Do not change anything inside the boxes while balancing the equation.
2. List the number of atoms of different elements present in the unbalanced equation.
3. Start balancing with the compound that contains the maximum number of atoms. It may be on the left side or right. In that compound, select the element with maximum number of atoms. Thus, first we will consider aluminium sulphate and the element which we will select first will be oxygen.
4. Now we need to balance sulphur and aluminum in aluminum sulphate. Choose any of the elements Sulphur is balanced, we will balance aluminum.
5. Examine the equation, pick up the element which is not balanced and balance it.
6. Finally, to check the correctness of the balanced equation count atoms of each element on both sides. This method of balancing the chemical equation is called as **hit and trial method** as we make trials to balance the equation by using the smallest whole number coefficient.
7. To make the chemical equation more informative, the physical state of the reactants and products is written along with their chemical formulae

(g) — for gaseous (I) — for liquid (s) — for solid

(aq) — for aqueous i.e. solution in water (Î) — used for gas

(down arrow) — used for precipitate. Sometimes the reaction conditions, such as temperature, pressure, catalyst etc are indicated above and below the arrow in the equation Given below is the balanced and complete equation of photosynthesis:—

$$6CO_2(aq) + 6H_2O(I) \xrightarrow[\text{chlorophyll}]{\text{sunlight}} C_6H_{12}O_6(aq) + 6O_2(aq)$$

Q. Balance the following chemical equations:

1. $Ca + AlCl_3 \rightarrow CaCl_2 + Al$
2. $NH_3 + NO \rightarrow N_2 + H_2O$
3. $H_3PO_3 \rightarrow H_3PO_4 + PH_3$
4. $Fe_2O_3 + C \rightarrow CO + Fe$
5. $FeS + O_2 \rightarrow Fe_2O_3 + SO_2$
6. $NH_3 + O_2 \rightarrow NO + H_2O$
7. $Si + S_8 \rightarrow Si_2S_4$
8. $Hg_2CO_3 \rightarrow Hg + HgO + CO_2$
9. $SiC + Cl_2 \rightarrow SiCl_4 + C$
10. $Pb_3O_4 + HCl \rightarrow PbCl_2 + H_2O + Cl_2$
11. $NH_4NO_3 \rightarrow N_2O + H_2O$
12. $Au_2O_3 \rightarrow Au + O_2$
13. $C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$
14. $Fe_3O_4 + H_2 \rightarrow Fe + H_2O$
15. $0_2 \rightarrow 0_3$
16. $FeCl_3 + NH_4OH \rightarrow Fe(OH)_3 + NH4CI$
17. $C_6H_6 + O_2 \rightarrow CO_2 + H_2O$
18. $C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$
19. $B_2O_3 + NaOH \rightarrow NaBO_2 + H_2O$
20. $Zn + AgNO_3 \rightarrow Zn(NO_3)_2 + Ag$

Information conveyed by a chemical equation

1. It gives the symbols and formulae of the reactants and products.
2. It tells us which substance or substances are taking part in the reaction and which product or products are being obtained. For example the equation tells that calcium carbonate reacts with hydrochloric acid to produce calcium chloride, water and carbon dioxide.
3. It gives the relative number of atoms and molecules of the reactants that take part in the reaction.
4. It tells us the relative number of the atoms and molecules of the products formed in the reaction.
5. It shows the ratio of the moles of the reactants and the products.

ABHYAS Academy, Behind Pragat Shiv Mandir, Near Govt. College, Nishat Cinema Road, Ambala Cantt.
Ph No. +91-171-2631595, 9416541198, e-Mail: anusethi1968@yahoo.com Website: www. abhyasonline.in

6. It tells us the ratio of the masses of the reactants and the products. The chemical equation representing the formation of water from hydrogen and oxygen may be briefly expressed as

Advantages of using a chemical equation:

1.The representation of a chemical reaction becomes easy. It saves time and space in writing.

2.In order to prepare a definite amount of the product, the amount of the reactant to be used can be calculated accurately.

3.The same chemical symbols are used all over the world and, therefore scientist faced no difficulty in understanding chemical equations.

Limitations of chemical equations:

1. A chemical equation does not indicate the physical state of the reactants and the products, i.e., it does not say whether the substances involved in the reaction are solids, liquids or the gases.
2. It does not indicate whether heat is evolved or absorbed as a result of reaction i.e., it does not say whether reaction is exothermic or endothermic.
3. It does not indicate the conditions of the reaction, i.e., it gives no idea about the pressure, temperature, concentration, presence of catalyst, etc, under which the reaction may occur.
4. It does not indicate whether the reaction is fast or slow.
5. Some reactions occur with an expansion. This is not indicated by the chemical equation.
6. It does not say anything about the actual amount of the reactants consumed or products formed. It gives only the ratio.

How to make equations more informative

1. The physical states of the reactants and the products are indicated by using symbols like s,l,g and aq in brackets after their symbols or formulae where s stands for solid, aq stand for aqueous solution, l for liquid and g for gas. Thus the equation may be expressed as
2. If a gas is evolved in the reaction, it is shown by an upward arrow line (↑) after the products. If a perceptible is formed, it is shown by a downward arrow line(↓) after the product.
3. Evolution or absorption of heat during the reaction is shown by writing the thermochemical equation. For an exothermic reaction, i.e., a reaction in which heat is evolved, we write + heat on the product side. For an endothermic reaction, i.e., a reaction in which heat is absorbed we write + heat on the reactant side.

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