Chemical Aspects of Elements | Plant Physiology

The following points highlight the five important chemical aspects of elements. The aspects are:

1. Isotopes.
2. Radioactivity.
3. Acids and Bases.
4. Hydrogen Ion Concentration (pH Scale).
5. Redox reactions.

Chemical Aspect of Element 1.

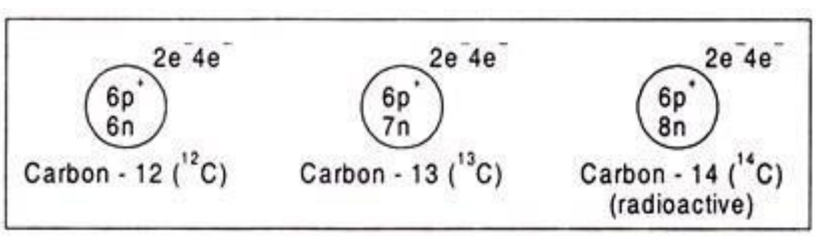
Isotopes:

The entity of an element is solely determined by the nuclear charge, i.e., the atomic number. In other words, the properties of an element are fundamentally based on its atomic number. The radioactive counterparts of various elements have the same atomic number but differ in atomic masses with their nonradioactive counterparts. Since the atomic number is the same, they have identical properties.

The atomic number is the ordinal number of the position of an element in the periodic table. So groups of elements which differ in their atomic masses but have the same atomic number have been given the name isotopes by Soddy.

The atomic masses of various isotopes of an element differ due to a difference in the number of charge-less neutrons in their nucleus, whereas the number of protons is fixed for all the isotopes of a given element.

As the chemical properties of an element are determined by the number of electrons in its atom, the isotopes of an element are identical in all chemical properties but differ in some physical properties like density, rate of diffusion, etc. Carbon has three natural isotopes, ^{12}C, ^{13}C, and ^{14}C, of which ^{14}C is radioactive. So, isotopes may be radioactive Isotopes or radioisotopes and nonradioactive isotopes.



Similarly, hydrogen has three isotopes — light hydrogen (^1H), deuterium (^2H) and tritium (^3H) or heavy hydrogen. Oxygen has three isotopes of mass numbers 16, 17 and 18, respectively.

Chemical Aspect of Element 2.

Radioactivity:

Radioactivity is a spontaneous and self-disruptive activity of several of the heavy isotopes of elements. The activity consists of the emission of a complex type of powerful radiation composed of three distinct kinds of rays, known as the alpha (α), beta (β) and gamma (γ) rays.

The result of this activity is the breaking up of the element itself for good, i.e., an irreversible self-disintegration. The activity remains unaffected by any external physical or chemical agents. Radioactivity may be natural or induced, i.e., artificially produced.

The number of atoms which disintegrate in unit time is the unit of radioactivity which is called the curie. It is defined as the activity of one gram of radium in which 3.71×10^{10} atoms

disintegrate per second. On account of the high activity and high cost of radium, the millicurie, a subunit which is 1/1000th part of a curie, is ordinarily used as the standard of radioactivity.

During radioactive decay an atom loses an alpha (α) particle with the loss of two protons and two neutrons, and becomes an atom of another element with an atomic number two digits smaller and an atomic weight four digits smaller. The rate of radioactive disintegration is governed by an exponential law.

The number of atoms that break up at any instant is proportional to the number present at that instant, or in other words, equal fractions of the radioactive atoms disintegrate in equal times.

In the successive disintegrations, any two adjacent elements may be considered as parent and daughter, the former being that which by its own decay produces the latter, e.g., radium is the parent element whereas the after emission daughter element is radon. In this way the parent of the following element will be the daughter of the preceding element.

The disintegration leads to the formation of a new element with different physical and chemical properties.

Chemical Aspect of Element 3.

Acids and Bases:

Substances which increase the hydrogen ion concentration in water are known as acids, and substances which increase the hydroxyl ion concentration in water are called bases. Therefore, an acid is a potential proton donor and a base is a potential proton acceptor.

Acid : $HA \rightleftharpoons H^+ + A^-$

$HCl \rightleftharpoons H^+ + Cl^-$

$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$

Base : $BOH \rightleftharpoons B^+ + OH^-$

$NaOH \rightleftharpoons Na^+ + OH^-$

A compound which can yield both H^+ and OH^- ions on dissociation, and which may. therefore, act both as an acid and a base, is termed as an amphoteric substance or ampholyte.

This dissociation theory though simple, also gives rise to several anomalies. Sodium hydroxide in aqueous solution liberates OH^- anions. So obviously it is a base. But though ammonia (NH_3) cannot liberate OH^- ions in this manner, it is a base because its addition to water increases the hydroxylion concentration.

The definition of an acid, on the other hand, is limited to aqueous systems, because hydrogen ion increase can be brought about by substances which themselves do not contain hydrogen. For example, CO_2 is an acid because its addition to water increases the hydrogen ion concentration so that the solution is acidic;

where HCO^-_3 represents the bicarbonate ion.

From the Bronsted and Lowry's definition of acid and base, the product other than H^+ formed by dissociation of an acid must be a base.

For example, when the acid HA dissociates, HA = H^+ + A^-, the anion A^- is a base because it serves as a proton acceptor in the reverse reaction. This base is called a conjugate base of the parent acid and they together comprise a conjugate pair. Thus, the chloride ion, Cl^- is the conjugate base of hydrochloric acid, HCl, and the acetate ion, CH_3COO^- is the conjugate base of acetic acid CH_3COOH.

Similarly, a base and its protonated derivative form a conjugate pair. Acetic acid is the conjugate acid of the acetate ion, and the NH_4^+ ion is the conjugate base of ammonia, NH_3.

The strength of an acid or base is an indication of its acidity or basicity. It is a measure of the effectiveness with which that compound behaves as an acid or a base. The strength of an acid is determined by the efficiency with which it acts as a proton donor.

This can be recorded in any one of the following ways:

(i) As the hydrogen ion concentration or pH of a dilute solution

(ii) As the percentage of acid molecules dissociated at equilibrium

(iii) As the dissociation constant of the acid

Chemical Aspect of Element 4.

Hydrogen Ion Concentration (pH Scale):

The term pH stands for potential of hydrogen and expresses the concentration of hydrogen ions (H^+) in a given solution. It is the negative logarithm of hydrogen ion concentration. In pure water the concentration of hydrogen ions is 1.0 x 10^{-7} moles/litre. The hydroxyl ion concentration of pure water is also the same. The actual degree of ionization of water is small and has a negative power.

Thus pH of pure water is:

$$\begin{aligned} pH &= -\log_{10} 10 \times 10^{-7} \\ &= -7 \times -\log_{10} 10 \\ &= -7 \times -1, [\text{as } \log_{10} 10 = 1] \\ &= 7.0 \end{aligned}$$

That is why pH 7 is considered neutral. The pH scale covers a range of values from 0 to 14. Any pH values below 7 indicate acidic solutions and any pH values above 7 indicate basic solutions.

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Thus if a solution has a pH of 6. It means that its hydrogen ion concentration is ten times greater (10^{-6}) than that of pure water (10^{-7}). Similarly, a solution of pH 8 has a hydrogen ion concentration ten times lesser (10^{-8}) than that of pure water. So the pH values differ by a factor of ten and solutions with low pH values are strongly acidic while solutions with high pH values are strongly basic.

5. Redox reactions.

An oxidation-reduction (redox) reaction is a type of chemical reaction that involves a transfer of electrons between two species. An oxidation-reduction reaction is any chemical reaction in which the oxidation number of a molecule, atom, or ion changes by gaining or losing an electron. Redox reactions are common and vital to some of the basic functions of life, including photosynthesis, respiration, combustion, and corrosion or rusting.

Key terms

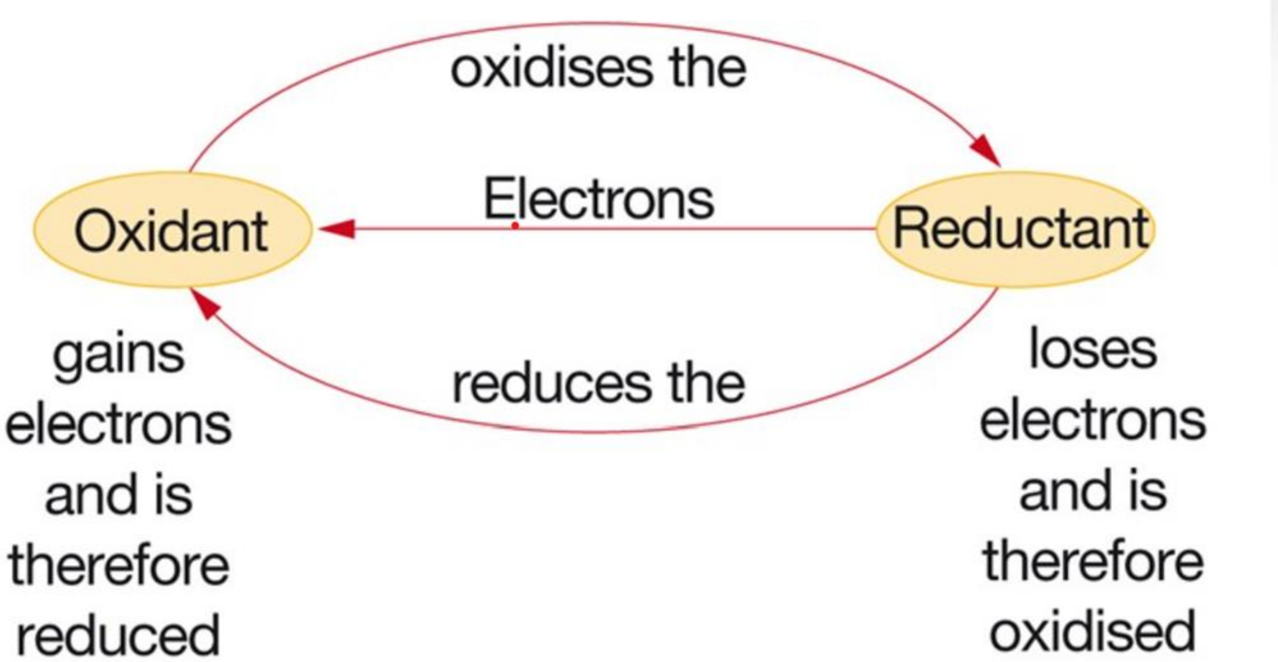
If electrons are transferred , it is a redox reaction.

A loss of electrons is called oxidation . A gain in electrons is called reduction.

Reduction and oxidation happen simultaneously, hence the name “ redox”.

An oxidizing agent (oxidant) accepts electrons and thus gets reduced.

A reducing agent (reductant) donates electrons and thus gets oxidized.



The **oxidant** is the species which *causes* oxidation and is itself reduced
The **reductant** is the species which *causes* reduction and is itself oxidised