2. Chemical bonding

Let us assess

1. Question

Complete the table given below and answer the following questions (Symbols used are not true.)

Element	Atomic number	Electronic configuration
P	9	2, 7
Q	17	.....
R	10	.....
S	12	.....

a) Which element in the table is the most stable one? Justify your answer.

b) Which element donates electrons in chemical reaction?

c) Write the chemical formula of the compound formed by combining element S with P.

Answer

Element	Atomic number	Electronic configuration
P	9	2, 7
Q	17	2,8,7
R	10	2,8
S	12	2,8,2

The maximum electrons which can be accommodated in first, second, third shells are 2,8,18 respectively. (The sum of numbers in electronic configuration must be equal to the atomic number). Filling starts from inner orbits. Accordingly, the configuration is given.

a) Element R is most stable.

Atoms with octet configuration are stable. The arrangement of 8 electrons in the outermost orbit of an atom is called octet configuration. These atoms are chemically stable. Atom R contains 8 electrons in its second shell (outermost), hence it is most stable.

b) Element S donates electrons.

Atoms get stability when they acquire octet structure. To acquire octet structure they either gain, lose or share electrons and try to get 8 electrons in the outermost shell.

Now in the case of S, it can easily lose 2 electrons and get stability (2^{nd} shell has octet configuration) instead of gaining 6 more electrons to get octet structure in 3^{rd} shell. So, it prefers to donate its 2 electrons and be stable.

c) SP_2 {S is magnesium (atomic no – 12) and P is fluorine (atomic no – 9), so it is MgF_2, magnesium fluoride}.

As explained above, S loses 2 electrons to be stable. P tries to gain 1 electron to get octet structure in 2^{nd} shell. So, the 2 electrons donated by S are acquired by 2 P atoms to form bond. Thus, both acquire stability and form compound.

2. Question

Examine the following chemical equations and answer the questions. (Hint: Atomic Number Mg=12 Cl=17)

$Mg + Cl_2 \rightarrow MgCl_2$

$Mg \rightarrow Mg^{2+} + ...$

$Cl + 1e^- \rightarrow .....$

a) Complete the chemical equations.

b) Which is the cation? Which is the anion?

c) Which type of chemical bond is present in $MgCl_2$?

Answer

a) $Mg \rightarrow Mg^{2+} + 2e^-$

$Cl + 1e^- \rightarrow Cl^-$

b) Magnesium ion – Mg^{2+} is cation and fluorine ion - F^- is anion.

c) Ionic bond

Explanation – Magnesium atom loses 2 electrons and acquires positive charge and thereby its called cation. Fluorine atom gains 1 electron, acquires negative charge and becomes anion. Both obtain octet configuration and become stable. The type of bond formed by the transfer of electrons is called ionic bond.

3. Question

The oxidation state of oxygen is -2. Find the oxidation state of the other atoms in the following compounds.

1. H_2O 2. H_2CO_3 3. HNO_3 4. H_3PO_4

Answer

Note: the sum of oxidation numbers of all elements in a compound is zero.

Consider x is the oxidation number of atoms whose oxidation number is to be found. Oxidation number of oxygen is -2. Applying the above rule-

1. 2x + (-2) = 0 ; x = 1 ; oxidation number of hydrogen is 1.

2. 2(1) + x + 3(-2) = 0 ; x = 4 ; oxidation number of carbon is 4.

3. 1 + x + 3(-2) = 0 ; x = 5 ; oxidation number of nitrogen is 5.

4. 3(1) + x + 4(-2) = 0 ; x = 5 ; oxidation number of phosphorous is 5.

4. Question

Electronegativity values of some elements are given. Using these values, find whether the following compounds are ionic or covalent.

(Electronegativity of Ca=1.0, O = 3.5, C = 2.5, S = 2.58, H = 2.2, F = 3.98)

Sulphur dioxide (SO_2) Water (H_2O)

Calcium fluoride (CaF_2) Carbon dioxide (CO_2)

Answer

Electronegativity difference between the constituent elements of a

compound decide the nature of compound. If the difference is 1.7 or more

than 1.7, then it generally shows ionic character and if its less than 1.7 it shows covalent character. Subtracting the respective electronegativity values of constituents gives difference.

1. Electronegativity difference of SO_2 is-

Electronegativity of O – Electronegativity of S

= 3.5 – 2.58 = 0.92

0.92 < 1.7 ; hence its covalent

2. Electronegativity difference of H_2O is-

Electronegativity of O – Electronegativity of H

= 3.5 – 2.2 = 1.3

1.3 < 1.7 ; hence its covalent

3. Electronegativity difference of CaF_2 is-

Electronegativity of F – Electronegativity of Ca

= 3.98 – 1.0 = 2.98

2.98 > 1.7 ; hence its ionic

4. Electronegativity difference of CO_2 is-

Electronegativity of O – Electronegativity of C

= 3.5 – 2.5 = 1.0

1 < 1.7 ; hence its covalent

5. Question

Some elements and their valences are given.

Element	Valency
Ba	2
Cl	1
Zn	2
O	2

a) Write the chemical formula of barium chloride.

b) Write the chemical formula of zinc oxide.

c) The chemical formula of calcium oxide is CaO. What is the valency of calcium?

Answer

a) $BaCl_2$

b) ZnO

c) 2

Valency is the combining capacity of an element. It can be treated as the number of electrons lost, gained or shared by an atom in a chemical combination.

The following are the steps to write chemical formulae from valency.

•First write the element with lower electronegativity.

•Exchange the valency of each element and write as suffix.

•Divide the suffix with common factor.

•If the suffix is 1, need not be written.

a) Ba is written first since it has lower electronegativity. The valences are exchanged and put as suffix, so Ba gets chlorine valency 1 as suffix and Cl gets barium valency 2 as suffix. Division by common factor 1 yields same. the suffix one is not needed. so, its simply written as $BaCl_2$.

b) Zn is written first since it has lower electronegativity. The valences are

exchanged and put as suffix, so Zn gets oxygen valency 2 as suffix and O gets zinc valency 2 as suffix. Division by common factor 2 yields Zn_1O_1. The suffix one is not needed. so, its simply written as ZnO.

c) CaO

We know that the valency of O is 2, as its given. Let's consider the valency of Ca is x. So, by following above rules, the chemical formula should be, Ca_2O_x. But the formula of calcium oxide is CaO which can be written as Ca_1O_1. So, the suffix are divided by 2 to get $Ca_1O_{x/2}$. Comparing $Ca_1O_{x/2}$ with Ca_1O_1 , we get that

x/2 = 1

x = 2.

Hence valency of Ca is 2.

Extended activities

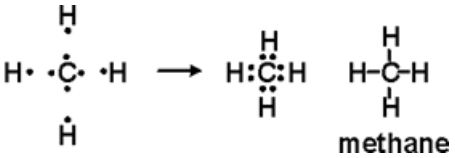
1. Question

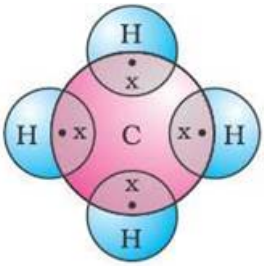
Draw the electron dot diagram of chemical bonds in methane (CH_4) and ethane (C_2H_6).

Answer

Methane

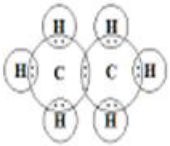
The atomic number of carbon is 6. Its configuration is 2,4. Its outermost orbit contains 4 electrons. The atomic number of hydrogen is 1. Its configuration is 1. Its outermost orbit contains 1 electron. Carbon and hydrogen thus share these electrons, so that carbon acquires octet structure and hydrogen acquires duplet structure and become stable. This is a covalent compound.



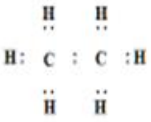


Ethane

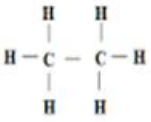
The atomic number of carbon is 6. Its configuration is 2,4. Its outermost orbit contains 4 electrons. The atomic number of hydrogen is 1. Its configuration is 1. Its outermost orbit contains 1 electron. In ethane, 2 Carbon and 6 hydrogens thus share these electrons, so that carbons acquire octet structure and hydrogens acquire duplet structure and become stable. This is a covalent compound.



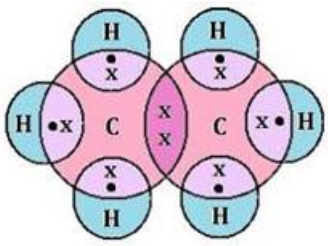
Structure of Ethane molecule



Electron dot structure of Ethane molecule

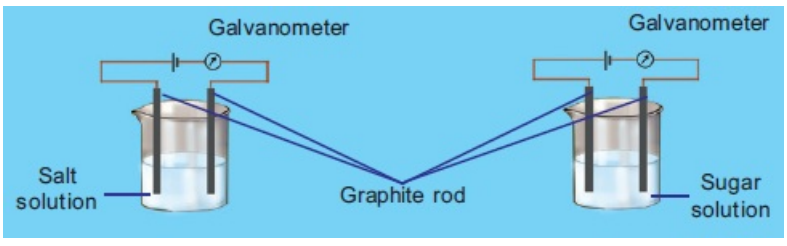


Structural formula of Ethane



2. Question

Perform the experiments arranging the apparatus as shown in figure.



Record your observations and identify what type of compounds sodium chloride and sugar are.

Answer

Salt solution such as sodium chloride (NaCl) conducts electric current because it has ions in it which freely move about in solution.

These ions are produced when sodium chloride dissolves in pure water to produce sodium ions (Na^+) and chloride ions (Cl^-). Oxidation is loss of electrons. Reduction is gain of electrons. Both occur here.

When you insert the graphite electrodes of a conductivity tester in the salt solution, the positive sodium ions (cations) usually move to the negative electrode (cathode), while the negative chloride ions (anions) move to the positive electrode (anion). This movement of ions to opposite ends of the electrodes allow electric current to flow through the solution.

On the other hand, sugar solution does not conduct an electric current because sugar ($C_{12}H_{22}O_{11}$) dissolves in water to produce sugar molecules. These sugar molecules are usually neutral (not charged), and so are unable to move to the opposite ends of the electrodes like the ions. Sugar doesn't dissociate into ions when it is mixed in water.

Galvanometer is a device which shows the direction of electric current in a circuit. So, in the case of salt solution, conduction of current occurs and galvanometer shows a deflection. In the case of sugar solution conduction doesn't occur, hence galvanometer shows no deflection.

Salt is ionic in nature and sugar is covalent in nature. Generally, solutions of ionic compounds conduct electricity and solutions of covalent compounds don't conduct electricity.

3. Question

P, Q, R, S are four elements. Their atomic numbers are 8, 17, 12 and 16 respectively. Find the type of chemical bond in these compounds formed by combining the following pairs of elements. Construct and exhibit the type of bonds using different substances (e.g. pearls).

(Electronegativity values: P=3.44, Q=3.16, R=1.31, S=2.5)

1. P, R

2. P, S

3. Q, R

Answer

Electronegativity difference between the constituent elements of a compound decide the nature of compound. If the difference is 1.7 or more

than 1.7, then it generally shows ionic character and if its less than 1.7 it shows covalent character. Subtracting the respective electronegativity values of constituents gives difference.

1. P and R

Electronegativity difference = 3.44 – 1.31 = 2.13

Ionic compound

2. P and S

Electronegativity difference = 3.44 – 2.5 = 0.94

Covalent compound

3. Q and R

Electronegativity difference = 3.16 – 1.31 = 1.85

Ionic compound

The electronic configuration of elements and valency decide the chemical formula of the compound. Electronic configuration of –

P is 2,6 (oxygen)

Q is 2,8,7 (chlorine)

R is 2,8,2 (magnesium)

S is 2,8,6 (sulphur)

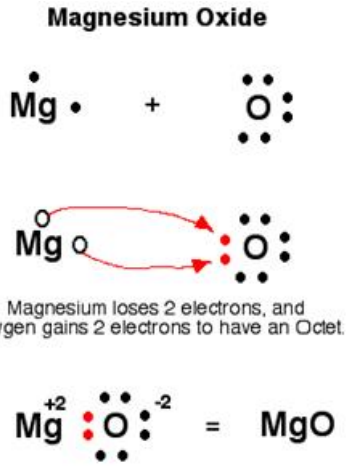
P tries to gain 2 electrons and obtain octet.

Q tries to gain 1 electron and obtain octet.

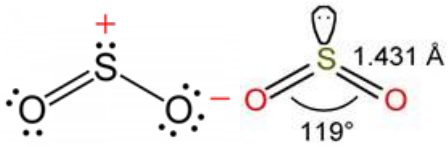
R tries to lose 2 electrons and get stability.

S tries to gain 2 electrons and obtain octet.

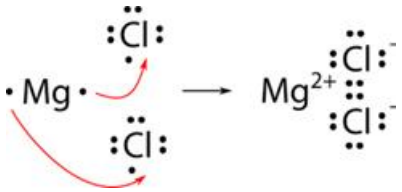
1. P and R form the compound PR (MgO) by transfer of electrons. It's a ionic compound.



2. P and S form the compound SP_2 (SO_2) by sharing of electrons. Its covalent compound.



3. Q and R form the compound RQ_2 ($MgCl_2$) by transfer of electrons which is a ionic compound.



The 2 electrons lost by magnesium are gained by 2 chlorine atoms.

Thus, $MgCl_2$ is formed.