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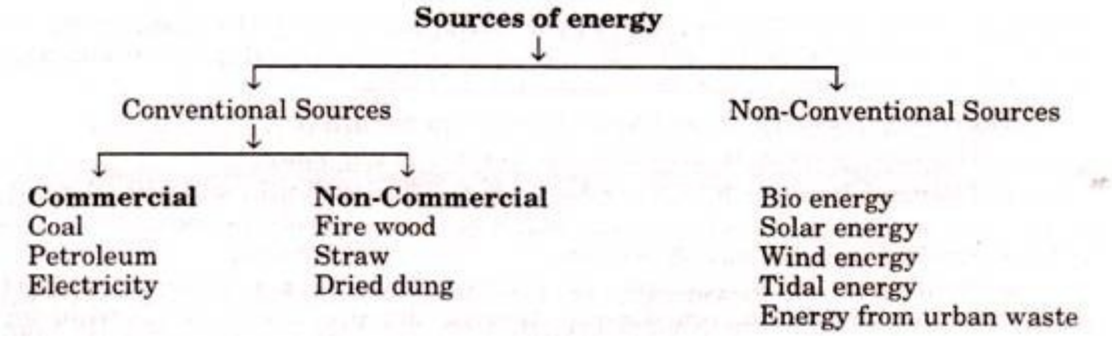
Conventional and Non-Conventional Sources of Energy

Energy is one of the most important component of economic infrastructure. Energy sources can be divided into two types based on how quickly they can be replenished:

- Conventional sources of Energy
- Non-conventional sources of Energy

The sources of energy are of following types:



1. **Conventional Sources of Energy:**

These sources of energy are also called non-renewable sources. These sources of energy are in limited quantity except hydro-electric power.

These are further classified as commercial energy and non-commercial energy:

Commercial Energy Sources:

These are coal, petroleum and electricity. These are called commercial energy because they have a price and consumer has to pay the price to purchase them.

(a) Coal and Lignite:

Coal is the major source of energy. Coal deposits in India are 148790 million tonnes. According to an estimate, coal reserves in India would last about 130 years. India is now the fourth largest coal producing country in the world. Coal deposits are mainly found in Orissa, Bihar, Bengal and Madhya Pradesh.

(b) Oil and Natural Gas:
In these days, oil is considered as the most important source of energy in India and the world. It is widely used in automobiles, trains, planes and ships etc. In India, it is found in upper Assam, Mumbai High and in Gujarat. The resources of oil are small in India. Despite tremendous increase in oil production. India still imports 70% of has oil requirements from abroad. As per current rate of consumption, oil reserves in India may last about 20 to 25 years.

Natural gas has been the most important source of energy since last two decades. It can be produced in two ways:
(i) With petroleum products as associated gas.

(ii) Free gas obtained from gas fields in Assam, Gujarat and Andhra Pradesh.

(c) Electricity:
Electricity is the common and popular source of energy. It is used in commercial and domestic purposes. It is used for lighting, cooking, air conditioning and working of electrical appliances like T.V., fridge and washing machine.

There are three main sources of power generation:
1. Thermal Power: It is generated in India at various power stations with the help of coal and oil. It has been a major source of electric power.

2. Hydro-electric power: It is produced by constructing dams over overflowing rivers. For example Bhakra Nangal Project, Damodar Valley Project and Hirakud Project etc.

3. Nuclear Power: Nuclear Power plants use radioactive substances such as uranium as fuel. This fuel is cheaper than coal. India has nuclear power plants at Tarapur, Kota (Rajasthan) Kalapakam (Chennai) Naroura (UP).

Non-Commercial energy Sources:
These sources include fuel wood, straw and dried dung. These are commonly used in rural India. Agricultural wastes like straw are used as fuel for cooking purposes. Animal dung when dried is also used for cooking purposes. The straw and dung can be used as valuable organic manure for increasing fertility of soil and in turn productivity.

2. Non-Conventional Sources of Energy:
As the fossil fuels are one of the biggest pollutants on the planet, demand for the non-conventional sources is developing. These sources not only instigate greenhouse effects but also reduce the dependence on oil and gas. Therefore, in order to meet the energy demand of the increasing population, the scientists are developing methods for us to tap into various non-conventional sources of energy, which are not only renewable but also non-polluting. Examples

are Natural sources like Bio energy, solar energy, wind energy and tidal energy. These are also pollution free hence can be used to produce clean form of energy by avoiding any wastage.

The various sources are given below:

1. Solar Energy: This is the most important non-conventional source of energy. Energy produced by harnessing the sunlight is called solar energy. For this process, solar photovoltaic cells are exposed to sunlight to produce electricity. Photovoltaic cells are those which convert sun light energy into electricity. Solar energy is used in solar cooker for cooking, in solar heater, in solar cells etc.

2. Wind Energy: This type of energy can be produced by harnessing wind power. It is used for operating water pumps for irrigation purposes.

3. Tidal Energy: Energy produced by exploiting the tidal waves of the sea is called tidal energy.

4. Bio Energy: This type of energy is obtained from organic matter. It is of two kinds:

(i) Bio Gas: Bio Gas is obtained from Gobar Gas Plant by putting cow dung into the plant. Besides producing gas this plant converts gobar into manure. It can be used for cooking, lighting and generation of electricity.

(ii) Bio Mass: Biomass is the organic matter that originates from plants, animals, wood, sewage. These substances burn to produce heat energy which then generates electricity. The chemical composition of biomass varies in different species but generally, biomass consists of 25% of lignin, 75% of carbohydrates or sugar. Biomass energy is also applicable for cooking, lighting, and generation of electricity. The residue left after the removal of biogas is a good source of manure.

5. Geothermal energy: Geothermal energy is the heat energy that we get from hot rocks present in the earth’s crust. So Geothermal wells release greenhouse gases trapped within the earth but these emissions are much lower per energy unit than the fossil fuels. This energy generally involves low running costs since it saves 80% on fossil fuels. Due to this, there is an increase in the use of geothermal energy. It helps in reducing global warming and does not create pollution.

Battery

A **battery** is an electrochemical device in which electrical energy is converted and stored in chemical form for storage. The chemical energy can then be easily reconverted into electrical energy.

There are two types of chemical batteries: Primary and secondary. A **primary battery** is not rechargeable and is designed to only last one discharge cycle, after which it must be replaced. The electrochemical reaction occurring inside in the primary cell is not reversible, thus rendering the cell un-rechargeable. As a primary cell is used, chemical reactions in the battery use up the chemicals that generate the power; when they are gone, the battery stops producing electricity.

Secondary batteries are rechargeable. The reaction can be reversed by running a current into the cell with a battery charger to recharge it, regenerating the chemical reactants. They can be discharged and recharged repeatedly thus they are repeated action cells.
A significant number of the modern electronic equipment we take for granted every day, such as mobile phones, laptop computers, music players, cameras and countless others are powered from rechargeable batteries. Secondary cells (rechargeable batteries) are in general more economical to use than primary cells. In these cells, the electrical energy is stored in the form of chemical energy. Therefore, these cells are also called storage cells or, accumulators. Lead-acid cell, (or lead storage cell), nickel-cadmium cell etc., are typical secondary cells.

Lead storage battery.

These batteries were invented in 1859 by French physicist Gaston Planté. The batteries used in automobiles, e.g., in cars, buses, trucks etc., are Lead storage batteries. The commercial forms of lead storage batteries consists of six or twelve lead Storage cells connected together**.** Despite being relatively heavy, lead-acid batteries are still preferred over other lightweight options owing to their ability to deliver large surges of electricity (which is required to start a cold engine in an automobile).
The chemical process of extracting current from a secondary battery (forward reaction) is called **discharging**. The method of regenerating active material is called **charging**.
In each cell, the anode and cathode plates are arranged alternately, and are separated from each other by separators. Separators are the sheets of insulating material placed in between the two plates. The anode and cathode plates are separately connected to each other. Thus, each electrode in a battery consists of many plates connected in parallels. This increases the surface area of each Electrode and hence increases the current producing capacity of the battery.

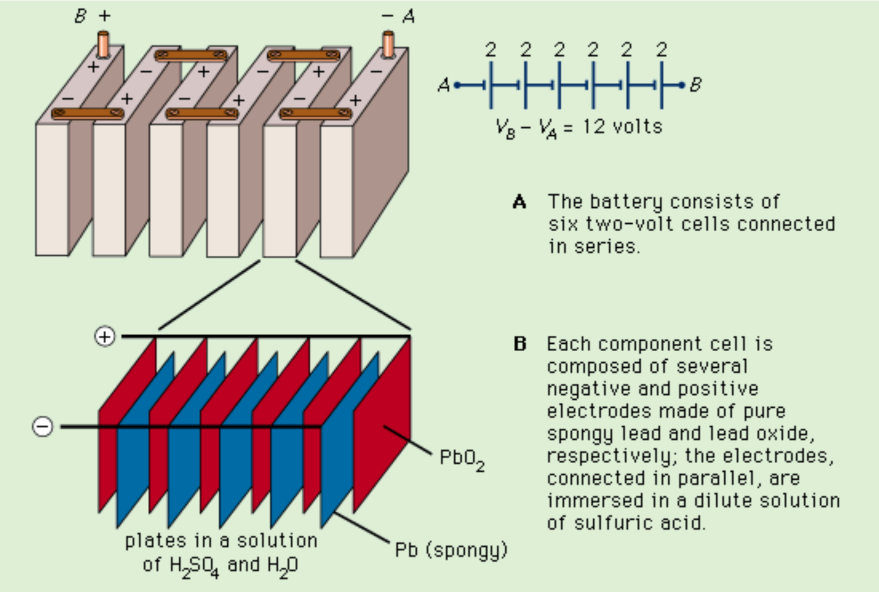
The plates in each electrode are called grids. The grids are made of lead or an alloy of lead and antimony. All cathode plates (grids) (marked as + ve) are coated with red-brown lead dioxide (PbO2).

Anode plates (marked as negative) are coated with spongy lead. The plates are immersed in dilute H_2SO_4 (40%) (sp. gravity : 1.15).

A lead storage cell may be represented as:

Pb|PbSO4(s)|H_2SO_4(40%)|PbO2(s)|Pb
(Anode) (Cathode)

In the discharged state, both the positive and negative plates become lead(II) sulfate ($PbSO_4$). When both the electrodes get covered with lead sulphate, reaction stops, and the cell is said to be dead or discharged. The electrolyte loses much of its dissolved sulfuric acid and becomes primarily water. The discharge process is driven by the conduction of electrons from the negative plate back into the cell at the positive plate in the external circuit (acts like a galvanic cell).



Negative plate reaction: $Pb(s) + HSO_4^-(aq) \rightarrow PbSO_4(s) + H^+(aq) + 2e^-$

Positive plate reaction: $PbO_2(s) + HSO_4^-(aq) + 3H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

Combining these two reactions, one can determine the overall reaction:

$Pb(s) + PbO_2(s) + 2H^+(aq) + 2HSO_4^-(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$

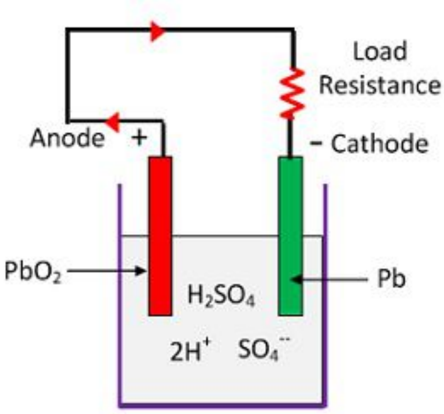
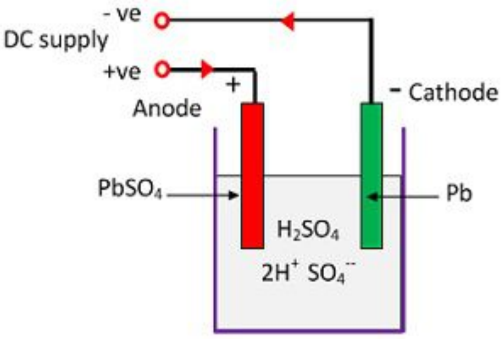


Fig: Discharging of lead acid battery

Charge Chemistry: The sulfuric acid existing in the lead discharge battery decomposes and needs to be replaced. Sometimes, the plates change their structure by themselves. Eventually, the battery becomes less efficient and should be charged or changed.

Lead-Acid Battery Charging

When car batteries spend considerable durations of time in their discharged states, the lead sulfate buildup may become extremely difficult to remove. This is the reason why lead-acid batteries must be charged as soon as possible (to prevent building up of lead sulfate). Charging of the lead batteries is usually done by providing an external current source.



A discharged lead storage cell however can be recharged by passing a direct current (dc) through the storage cell. This direct current reverses the electrode reactions, and converts the lead sulphate back to lead and lead dioxide on the respective electrodes. During charging, the negative electrode of the storage cell is connected to the negative of the dc source, and the positive electrode is connected to the positive of the dc source. While recharging, the lead acid battery functions like an electrolytic cell

Negative plate reaction: $PbSO_4(s) + H^+(aq) + 2e^- \rightarrow Pb(s) + HSO_4^-(aq)$

Positive plate reaction: $PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + HSO_4^-(aq) + 3H^+(aq) + 2e^-$

Combining these two reactions, the overall reaction is the reverse of the discharge reaction:

$2PbSO_4(s) + 2H_2O(l) \rightarrow Pb(s) + PbO_2(s) + 2H^+(aq) + 2HSO_4^-(aq)$

The charging reaction is the exact opposite of the discharge reaction.

Drawbacks: Although the batteries are reliable, they have a limited life, are heavy to ship, and contain toxic materials that require specific removal methods at the end of their useful life.

Nickel metal hydride battery

A **Nickel metal hydride battery**, abbreviated **NiMH** or **Ni–MH**, is a type of rechargeable battery.

The chemical reaction at the positive electrode is similar to that of the nickel–cadmium cell (NiCd), with both using nickel oxide hydroxide (NiOOH). However, the negative electrodes use a hydrogen-absorbing alloy instead of cadmium.

The NiMH cell bears many similarities to the older NiCd cell technology, using many similar constituents. NiMH battery technology has overtaken that of its NiCd brother because of their lower environmental impact. The use of cadmium is of particular concern, and therefore the use. While the use of toxic cadmium is removed from the NiMH cells the mining and processing of the other metals used poses some environmental threats. Fortunately, when the NiMH batteries reach end of life, most of the nickel can be recovered with relative ease. The NiMH cell consists of three main elements:

- ***Positive electrode:*** The positive electrode of the NiMH battery is nickel hydroxide having the same composition as the positive electrode in a NiCd cell. The nickel oxide - hydroxide electrode only exchanges a proton in the charge-discharge reaction, and this results in a very small change in size, resulting in a high level of mechanical stability, and this in turn results in a longer cycle life.

  On the positive electrode, nickel oxyhydroxide, NiO(OH), is formed:
  $Ni(OH)_2 + OH^- \rightleftharpoons NiO(OH) + H_2O + e^-$

- ***Electrolyte:*** The electrolyte in the NiMH cell is an aqueous solution of potassium hydroxide, KOH, which has a very high conductivity. The solution does not enter into the NiMH cell reaction to any significant extent. It is found that the electrolyte concentration remains almost constant over the charge / discharge cycle. This is important because the concentration of the electrolyte is the main contributor to the cell resistance. This means that the performance of the cell remains almost the same over the entire charge range.

- ***Negative electrode:*** The active material for the negative electrode is actually hydrogen. However, it is not physically possible to use hydrogen directly and therefore the hydrogen is stored in the NiMH cell as a metal hydride which also serves as the negative electrode.

The negative electrode reaction occurring in a NiMH cell is

$H_2O + M + e^- \rightleftharpoons OH^- + MH$

Overall reaction

$Ni(OH)_2 + M \rightleftharpoons NiO(OH) + MH$

These reactions are reversible during charging. NiMH have a nominal single cell voltage of 1.2 V, which is fixed by the battery chemistry. In order to obtain higher voltages, cells are put together in series. NiMH replaces Ni-Cad batteries in portable electronics.
Some of the most important characteristics of NiMH Battery are as follows:

Nickel Metal Hydride Battery Characteristics	
Nominal Voltage	1.2V
Specific Energy	60-120W.h/kg
Energy Density	140-300W.h/L
Specific Power	250-1000 W/kg
Charge/Discharge Efficiency	66%

Self discharge rate	30% per month (temperature dependent)

The Specific Energy refers to the amount of energy that can be stored per unit weight. This value is very important for portable equipment as heavy batteries will be difficult and energy consuming to move around. The Specific Energy of NiMH batteries is much higher than Ni-Cad batteries. It is however lower than Lithium batteries.

Energy Density describes how much energy can be stored per unit volume. Again, for portable electronic equipment, the space required for a given storage capacity is an important figure. The Energy Density for NiMH is much higher than the Ni-Cad Batteries, Lead-acid batteries. NiMH contains no toxic metals. Applications include mobile phones and laptop computers. Specific Power refers to the maximum amount of power that can be delivered. In electrical terms, this is the maximum Discharge Rate of the battery. Specific power of NiMH is less compared to Ni-Cad.

NiMH also has high self-discharge of 30 % per month. Modifying the hydride materials will reduce the self-discharge and reduces corrosion of the alloy, but this leads to decreases in specific energy. The Life time of Nickel Metal Hydride is less compared to Ni-Cad and Li-ion but more than the lead acid and comparable with lithium polymer.

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Questions from previous years, Ancillary Chemistry, Sem IV

1a. Write the electrochemical reaction occurring in a lead storage battery. Name the materials which are used as anode and cathode in the same. 4 marks, 2014-15.

b. How do the hydrogen hydrides produce energy? Why are the same considered a cleaner and everlasting fuel as compared to petrochemicals. 4 marks.

2a. Justify “Hydrogen is a non polluting fuel”. 2 marks,2016-17

b. Differentiate between Conventional and non-conventional sources of energy.2017-18

c. Comment on the chemical reaction occurring in a lead storage battery. 2 marks, 2016-17

3. What is a battery? How are batteries classified based on their use? Write a brief note on lead storage battery. 6 marks, 2018-19

4. Desribe the lead storage battery. How far is it helpful in our day-to-day life? 4 marks, 2012-2013.

Extraction of Iron

Iron is extracted from iron ore in a huge container called a **blast furnace**. It's a long process which begins with Concentration followed by Calcination and Smelting of ore. The first step of the metallurgical operation involves removing impurities like soil etc by crushing and washing of ore hence called concentration.

Calcination:

The concentrated ore is heated in limited supply of air on the shallow hearth of reverberatory furnace. This process is performed to remove moisture, CO_2, impurities of sulphur, arsenic. Ferrous oxide is also oxidized to ferric oxide. During calcination, flowing changes occur.

i. Moisture and volatile impurities are driven out.

ii. Non-metallic impurities like S, P, etc are removed as their oxides.

$S + O_2 \rightarrow SO_2$

$P_4 + 5O_2 \rightarrow 2P_2O_5$

iii. If any carbonate is present then it dissociates to give oxide.

$FeCO_3 \rightarrow FeO + CO_2$

Smelting

The calcined ore is mixed with lime stone ($CaCO_3$) (Flux) and ore and charged into blast furnace. On passing preheated compressed air inside the furnace, four distinct zones are formed.

a. Zone of combustion: This zone lies at the bottom of the blast furnace where coke burns in presence of pre heated air forming CO_2 and heat.

$C + O_2 \rightarrow CO_2 + \text{heat}$

Here, the temp is maintained above 1500^0c. This produces the energy required for the smelting of iron.

b. Zone of Fusion: This zone lies above zone of combustion. Here upcoming CO_2 is reduced by red-hot coke to carbon monoxide. The reaction is endothermic and temp falls to 1200^0 - 1300^0 C

$CO_2 + C \rightarrow 2CO - \text{heat}$

Red-hot

The spongy iron formed in zone of reduction melts here and any oxide escaped reduction is reduced here.

$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

c. Zone of slag formation: This zone lies above zone of fusion and it has temp of about 1000^0c. In this zone calcium carbonate dissociate forming (calcium oxide) which combines with silica (SiO_2) present as impurity in Haematite forming calcium silicate ($CaSiO_3$) as slag.

$CaCO_3 \rightarrow CaO + CO_2$

$CaO + SiO_2 \rightarrow CaSiO_3$

The slag is lighter than molten iron and floats on the surface of the iron. The formation of slag prevents the oxidation of iron.

d. Zone of Reduction: This is the most important zone and has temperature of 600-700^{0}C. In this zone Fe_2O_3 is reduced to iron by CO in three steps. The oxygen must be removed from the iron(III) oxide in order to leave the iron behind. Reactions in which oxygen is removed are called **reduction reactions**. Carbon is more reactive than iron, so it can displace iron from iron(III) oxide. Iron(III) oxide is reduced to iron, and the carbon is oxidised to carbon dioxide. In the blast furnace carbon gets converted to carbon monoxide which is used to reduce iron(III) oxide.

$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$
$Fe_3O_4 + CO \rightarrow 3FeO + CO_2$
$FeO + CO \rightarrow Fe + CO_2$
From the bottom of blast furnace, molten slag and molten iron are tapped out. This iron is impure and is called pig-iron.

The iron manufactured in Blast Furnaces contain about 3 – 4 % of Carbon and smaller quantities of many other impurities such as sulfur, Silicon, etc. This is called Pig Iron. It is a hard but brittle metal and the impurities severely hamper its strength. Carbon seems to play a significant role in influencing the brittleness and hardness balance in iron. To further reduce the carbon content of pig iron, it is melted again with scraps of iron and coke and subjected to the blast of hot air. This kind of iron is called Cast Iron and has a slightly lower carbon content 2 – 3 %. This is even harder than pig iron.

Wrought Iron/ Malleable Iron

Wrought Iron is the purest form of iron available commercially and is prepared from cast iron by heating cast iron in a furnace lined with Haematite (Fe_2O_3). The Haematite reacts with Carbon in the cast iron to give pure iron and carbon monoxide gas which escapes.

$Fe_2O_3+3C \rightarrow 2Fe+3CO$
Limestone is then added as flux, and it creates the slag. Impurities such as S, Si pass into the slag and the slag later can be easily separated to yield pure iron.

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Energy and Covalent Bond Formation

Most atoms attain a lower potential energy when they are bonded to other atoms than when they are separated. Consider two isolated hydrogen atoms that are separated by a distance large enough to prevent any interaction between them. At this distance, the potential energy of the system is said to be equal to zero

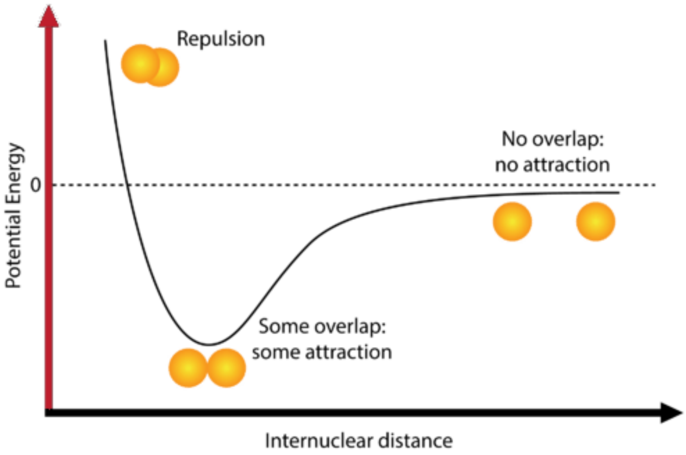

Fig: The graph shows how the potential energy of two hydrogen atoms changes as a function of their separation distance.

As the atoms approach one another, their electron clouds gradually begin to overlap. Now there are several interactions which begin to occur. One is that the single electrons that each hydrogen atom possesses begin to repel each other. This repulsive force would tend to make the potential energy of the system increase. However, the electron of each atom begins to be attracted to the nucleus of the other atom. This attractive force tends to make the potential energy of the system decrease.

As the atoms first begin to interact, the attractive force is stronger than the repulsive force and so the potential energy of the system decreases, as seen in the diagram. The lower potential energy increases the stability of the system. As the two hydrogen atoms move closer and closer together, the potential energy is at its lowest possible point. If the hydrogen atoms move any closer together, a third interaction begins to dominate and that is the repulsive force between the two positively-charged nuclei. This repulsive force is very strong as can be seen by the sharp rise in energy at the far left of the diagram.

The point at which the potential energy reached its minimum represents the ideal distance between hydrogen atoms for a stable chemical bond to occur. This type of chemical bond is called a covalent bond. A **covalent bond** is a bond in which two atoms share one or more pairs of electrons. The single electrons from each of the two hydrogen atoms are shared when the atoms come together to form a hydrogen molecule (H2)

Factors affecting bond length

(i) The bond length increases with the increase in the size of the atoms. For example, bond length of H-X are in the order, HI > HBr > HCl > HF.

(ii) The bond length decreases with the multiplicity of the bond. Hence, bond length of the carbon-carbon bonds are in the order, $C \equiv C < C = C < C - C$.

(iii) As the s-orbital is smaller in the size, greater the s-character shorter is the hybrid orbital and hence shorter is the bond length.

For instance, $sp^3\,C-H > sp^2\,C-H > sp\,C-H$

(iv) Polar bond length is generally smaller than the theoretical non-polar bond length.

(2) **Bond energy**: The amount of energy needed to break one mole of the bonds of a particular type so as to separate them into the gaseous atoms is known as **bond dissociation energy** or simply the **bond energy**. The greater is the bond energy, the stronger is the bond. Bond energy is generally expressed in KJ Mol^{-1}.

Factors affecting bond energy

(i) The greater size of the atom, greater is the bond length and less will be the bond dissociation energy which means less is the bond strength.

(ii) For bond between the two similar atoms, greater is multiplicity of the bond, greater will be the bond dissociation energy.

(iii) The greater the number of the lone pairs of electrons present on the bonded atoms, the greater will be the repulsion between the atoms and thus less is the bond dissociation energy.

(iv) The bond energy increases as hybrid orbitals have greater amount of *s* orbital contribution. Therefore, bond energy decreases in the following order, $sp > sp^2 > sp^3$.

(v) The greater electronegativity difference, the greater is the bond polarity and thus greater will be the bond strength that is bond energy, $H{-}F > H{-}Cl > H{-}Br > H{-}I$.

Factors affecting bond angle

(i) The Repulsion between atoms or the groups attached to the central atom might increase or decrease the bond angle.

(ii) In the hybridisation as the s character of the s hybrid bond increases, bond angle increases.

Bond type	sp^3	sp^2	sp
Bond angle	109º28'	120°	180°

(iii) By increasing the lone pair of electrons on the central atom, the bond angle decreases approximately by 2.5%.

	CH_4	NH_3	H_2O
Bond angle	109º	107°	105°

Due to absence of lone pairs of electrons on the C atom of CH_4, the bond angle in this molecule is equal to expected tetrahedral angle (109.5^0). In NH_3, there is one lone pair of electrons on N atom. We know that (VSEPR theory)

l.p-b.p repulsion > b.p-b.p repulsion, thus H-N-H bond angle reduces to 107.5^0 in NH_3

In H_2O, there are two lone pairs and two bond pairs of electrons. We know that (VSEPR theory)

l.p-l.p repulsion > l.p-b.p repulsion > b.p-b.p repulsion, thus two lone pairs in H_2O molecule tend to be far apart from each other as much as possible. Hence H-O-H bond angle gets reduced compared to NH_3

Similarly, bond angle of $PH_3>H_2S$ and bond angle of $AsH_3>H_2Se$

(iv) *If the electronegativity of central atom decreases, the bond angle decreases.*

	H_2O	$>H_2S$	$>H_2Se$	$>H_2Te$
Bond angle	104.5°	92.2°	91.2°	89.5°

O atom is more electronegative than S atom, thus bonding electron pair of O-H bond in H_2O is shifted more towards O atom compared to bonding electron pairs of S-H bond in H_2S. Thus, electron density near O atom is more compared to S atom. Thus b.p-b.p repulsion in H_2O is greater than H_2S. Thus, H-O-H bond angle is greater than H-S-H bond angle. Electronegativity of the central atoms follows the order O > S > Se > Te, hence the bond angle also decreases in the above mentioned order.

In case the central atom remains same, bond angle increases with decrease in electronegativity of the surrounding atom.

	PCl_3	PBr_3	PI_3 ,	$AsCl_3$	$AsBr_3$	AsI_3
Bond angle	100°	101.5°	102°	98.4°	100.5°	101°

Q. The F-O-F bond angle in OF_2 is 103.2^o whereas the Cl-O-Cl bond angle in OCl_2 is 111^0.

Explanation: F atom is more electronegative than O atom. The bonding pair of electrons of O-F bond will shift more towards F atom compared to bonding electron pairs of O-Cl bond. Since bond pairs of electrons shift away from the central atom, b.p-b.p repulsion decreases in OF_2 compared to OCl_2 molecule. Thus F-O-F bond angle is less compared to Cl-O-Cl bond angle.

Old questions:

Q1. Describe the changes in potential energy taking place during bond formation between two atoms. Ancillary Chem, Sem IV, 2012-2013

Q2. Arrange C_2H_6, C_2H_4, C_2H_2 in terms of increasing carbon carbon bond length. 2 marks

Q3. Discuss the energetics of formation of $MgCl_2(s)$ from its constituents Mg(s) and $Cl_2(g)$. 4 marks, 2014-15, 2016-17.

Q4. Compare bond angles in CH_4, NH_3 and H_2O.

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