

# Molecular Model Kit

## आणविक मॉडल किट

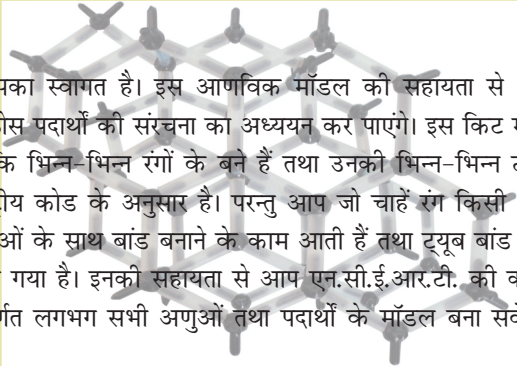


*A journey through  
the molecular world*

आणविक जगत की सैर




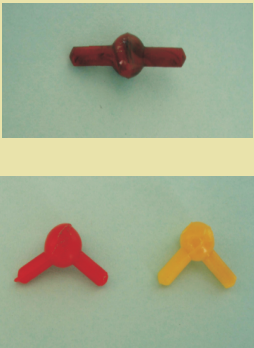
राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्  
NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING






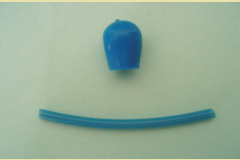
आइए, अणु जगत में आपका स्वागत है। इस आणविक मॉडल की सहायता से आप सरल कार्बनिक तथा अकार्बनिक अणुओं तथा ठोस पदार्थों की संरचना का अध्ययन कर पाएंगे। इस किट में प्लास्टिक से बने विभिन्न प्रकार के परमाणु हैं जो कि भिन्न-भिन्न रंगों के बने हैं तथा उनकी भिन्न-भिन्न टाँगें हैं। रंगों का एक खास मतलब है जो कि अंतर्राष्ट्रीय कोड के अनुसार है। परन्तु आप जो चाहें रंग किसी भी परमाणु के लिए प्रयोग कर सकते हैं। टाँगें परमाणुओं के साथ बांड बनाने के काम आती हैं तथा ट्यूब बांड का काम करती है जिसका विवरण सारणी 1 में किया गया है। इनकी सहायता से आप एन.सी.ई.आर.टी. की कक्षा 11 व 12 की रसायन विज्ञान की पुस्तकों में वर्णित लगभग सभी अणुओं तथा पदार्थों के मॉडल बना सकेंगे।

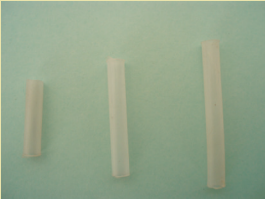

Welcome to the world of molecules. Explore the structure of simple organic, inorganic molecules and solids by using this molecular model kit. This self-learning kit contains various plastic-moulded atoms having a number of prongs and shapes in various colours. The colours have a typical meaning according to International Colour Code, but you can make a colour mean whatever you like if needed. Prongs are used to make bonds with other atoms. Tubings are used for making bonds. The kit can be used to make models for most of the molecules as discussed in the NCERT books of Classes XI and XII.

### 1. List of Items in the Kit

| S. No | ITEM'S NAME                                  | PICTURE   | USES   |
|-------|--|---|--|
| 1.    | One-prong atom                               |   | For linking the atom by single bond.   |
| 2.    | Two-prong atom<br>(a) Linear<br><br>(b) Bent |  | For linking the atom to two other of atoms by two single bonds at an angle of 180 degree between them with sp hybridisation. For linking the atom to other atoms by two single bonds at an angle of 90 degree. |

| S. No | ITEM'S NAME     | PICTURE   | USES   |
|-------|-----------------|---|--|
| 3.    | Four-prong atom |   | <p>For linking the atom to two other atoms by two single bonds with 180 degree between them with sp hybridisation.</p> <p>For linking the atom to two other atoms by two single other atoms by two single bonds with an angle of 90 degree.</p>  |
| 4.    | Five-prong atom |  | <p>(a) For linking the carbon atom with sp<sup>3</sup> hybridisation to four other atoms to make tetrahedral structure.</p> <p>(b) For linking the atom to three other atoms with tetrahedral angle and one lone pair of electrons (nitrogen).</p> <p>(c) For linking the atom to two other atoms with nearly tetrahedral angle and two lone pair of electrons (oxygen).</p> |

| S. No. | ITEM'S NAME    | PICTURE   | USES  |
|--------|----------------|---|---|
| 5.     | Six-prong atom |   | <p>(a) For linking the atom with <math>sp^3d^2</math> or <math>d^2sp^3</math> hybridisation to six other atoms with octahedral geometry.</p> <p>(b) For linking the atom to four other atoms with square planar geometry and showing two lobes of orbitals/two lone pairs.</p> <p>(c) For linking the carbon atom with <math>sp</math> hybridisation to two other atoms and to show pi electrons of two pi bonds in a triple bond .</p> |
| 6.     | Orbital lobes  |  | <p>For showing orbitals/lone pairs of electrons.</p>  |

| <b>S. No.</b> | <b>ITEM'S NAME</b> | <b>PICTURE</b>   | <b>USES</b>  |
|---------------|--------------------|--|--|
| 7.            | Linkers            |  | For showing sigma bonds and ionic bonds between two atoms. |
| 8.            | Sleeve             |  | For showing pi bonds between two atoms.                    |

## 2. Making Structures of Simple Molecules

### I. STRUCTURES OF SIMPLE MOLECULES, APPLICATION OF VSEPR THEORY

#### 1. Molecule : $\text{BeCl}_2$ (Beryllium Chloride), Shape : Linear

*Items required*

- (i) Two-prong brown linear atom (Be) - 1 pc
- (ii) One-prong green atom (Cl) - 2 pc
- (iii) Linkers (small) - 2 pc

*How to make*

$\text{BeCl}_2$  is a linear molecule. Take a two-prong linear brown atom (Be) and attach two one-prong green atoms (Cl) to it with small linkers.



#### 2. Molecule : $\text{AlCl}_3$ (Aluminium Chloride), Shape : Trigonal planer

*Items required*

- (i) Five-prong black atom (Al) - 1 pc
- (ii) One-prong green atoms (Cl) - 3 pc
- (iii) Linkers (small) - 3 pc

*How to make*

Take a five-prong atom black (Al) and attach three one-prong green atoms (Cl) with the help of small linkers to its three prongs in a plane.



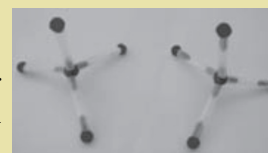
**3. Molecule : CH<sub>4</sub> (Methane), Shape : Tetrahedral**

*Items required*

- (i) Four- prong black atom (C) - 1 pc
- (ii) One- prong white atoms (H) - 4 pc
- (iii) Linkers(small) - 4 pc

*How to make*

Take the four-prong black atom (C) and attach four one-prong white atoms(H) with the help of small linkers to the four prongs of black atom in a plane.



**4. Molecule : SF<sub>4</sub> (Sulphur Tetrafluoride), Shape : Sea-Saw**

*Items required*

- (i) Five-prong brown red atom (S) - 1pc
- (ii) One-prong green atoms (F) - 4 pc
- (iii) Small linkers - 4 pc
- (iv) Orbital lobe - 1 pc

*How to make*

Take the five-prong brown/red atom(S) and attach one orbital lobe to its one of the three prongs which are in the same plane. Now attach four one-prong green atoms(F) to the remaining four prongs of





(S) atom with small linkers. Keep the molecule on table such that the orbital lobe is pointing upward. Out of the four (F) atoms only three would touch the table surface and the molecule can be moved like a sea-saw.

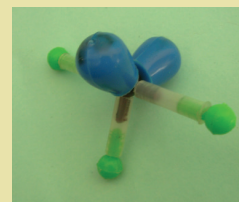
**5. Molecule :  $\text{BrF}_3$  (Bromine Trifluoride) Shape : T shaped**

*Items required*

- (i) Five – prong brown atom (Br) - 1 pc
- (ii) One-prong green atoms (F) - 5 pc
- (iii) Orbital lobes - 2 pc
- (iv) Small linkers - 3 pc

*How to make*

Take the five-prong brown atom (Br) and attach two orbital lobes to its two of the three prongs which are in the same plane. Now attach three one-prong green atoms (F) to the remaining three prongs of (Br) atom with small linkers.



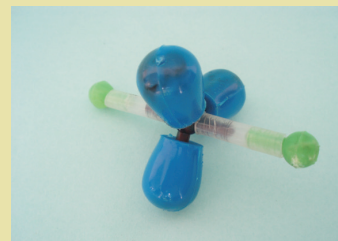
**6. Molecule :  $\text{I}_3$  (Triiodide), Shape : Linear**

*Items required*

- (i) Five-prong brown atom (I) - 1 pc
- (ii) One-prong brown green atoms (I) - 2 pc
- (iii) Orbital lobes - 3 pc
- (iv) Small linkers - 2 pc

*How to make*

Take the five-prong brown atom(I). Attach three orbital lobes to the three prongs which are in one plane which are in one plane/same plane. Now attach two one-prong green atoms (I) to the remaining two prongs of central I atom with small linkers.



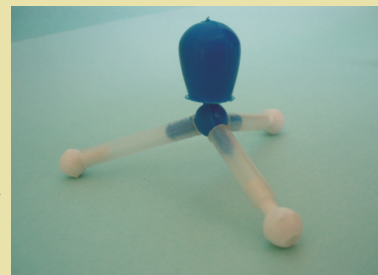
**7. Molecule :  $\text{NH}_3$  (Amonia), Shape : Trigonal pyramidal**

*Items required*

- (i) Four-prong blue atom (N) - 1pc
- (ii) One-prong white atom (H) - 3 pc
- (iii) Orbital lobe - 1 pc
- (iv) Small linkers - 3 pc

*How to make*

Take the four -prong blue atom (N) and attach three one-prong white atoms (H) with small linkers to its three prongs. On the remaining prong of (N) atom attach the orbital lobe.



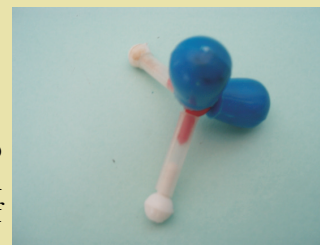
**8. Molecule : H<sub>2</sub>O (Water), Shape : Bent**

*Items required*

- (i) Four-prong red atom (O) - 1 pc
- (ii) One-prong white atoms(H) - 2 pc
- (iii) Orbital lobes - 2 pc
- (iv) Small linkers - 2 pc

*How to make*

Take the four-prong red atom (O) and attach two one-prong white atoms (H) to two prongs with small linkers. On the remaining two prongs of (O) atom, attach two orbital lobes.



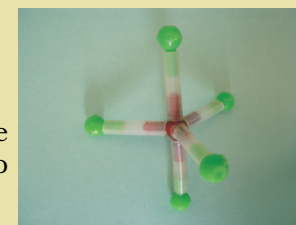
**9. Molecule : PCl<sub>5</sub> (Phosphorus Pentachloride), Shape : Trigonal Bipyramidal**

*Items required*

- (i) Five-prong red atom (P) - 1 pc
- (ii) One-prong green atoms (Cl) - 5 pc
- (iii) Small linkers - 5 pc

*How to make*

Take the five-prong red atom (P) and attach five one-prong green atoms (Cl) with small linkers to all the five prongs.



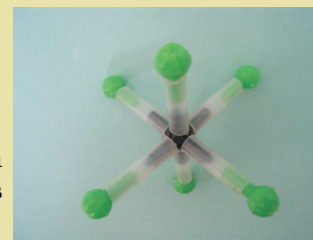
**10. Molecule : SF<sub>6</sub> (Sulphur Hexafluoride), Shape : Octahedral**

*Items required*

- (i) Six-prong orange atom (S) - 1pc
- (ii) One-prong green atom (F) - 6 pc
- (iii) Small linkers- 6 pc

*How to make*

Take the six-prong orange atom (S) and attach six one-prong green atoms (F) with small linkers to all the sides.



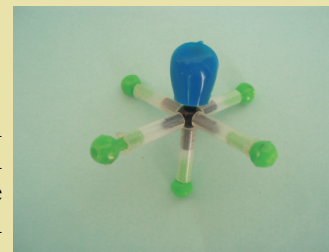
**11. Molecule : BrF<sub>5</sub> (Bromine Pentafluoride), Shape : Square pyramidal**

*Items required*

- (i) Six-prong green atom (Br) - 1 pc
- (ii) One-prong green atom (F) - 5 pc
- (iii) Orbital lobe - 1 pc
- (iv) Small linkers - 5 pc

*How to make*

Take the six-prong green atom (Br) and attach the five one-prong green atoms (F) with small linkers four in the same plane and one perpendicular to them. Now attach the orbital



lobe to the remaining prong of (Br) atom which is perpendicular to the four prongs in the same plane.

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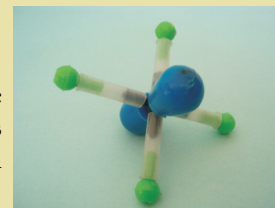
**12. Molecule :  $\text{XeF}_4$  (Xenontetrafluoride), Shape : Square planer**

*Items required*

- (i) Six-prong brown atom (Xe) - 1 pc
- (ii) One-prong green atoms (F) - 4 pc
- (iii) Orbital lobes - 2 pc
- (iv) Small linkers - 4 pc

*How to make*

Take the six-prong brown atom (Xe) and attach the four one-prong green atoms (F) to its four prongs which are in the same plane. Now attach two orbital lobes to the remaining prongs.



## II. NETWORK AND OTHER INORGANIC MOLECULES

### 1. Allotropes of Carbon : Diamond and Graphite

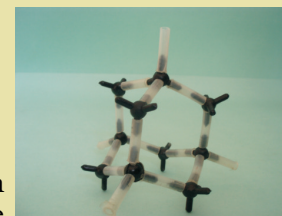
#### (A) Diamond

*Items required*

- (i) Four-prong black atom (C) : 10 pc
- (ii) Small linkers : 16

*How to make*

Make four tetrahedral units with four-prong atom and linkers. Join three of them through three more four-prong atom to make hexagonal ring in chair form. Join the fourth tetrahedral unit to this ring through three four-prong atom keeping it above the ring as shown in the picture. While doing so, it will be observed that this linking is possible only with chair conformation.



#### (B) Graphite

*Items required*

- (i) Five-prong black atom (C)
- (ii) Small linkers
- (iii) Large linkers

*How to make*

Model of Graphite can be constructed in two steps.

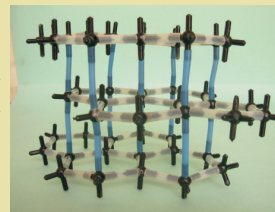
(i) Making different layers

Take 13 five – Prong black atom (C). Link them with small linkers to make one layer. For linking them, use the three prongs which are in the same plane. This will make one layer. Now make two more similar layers.

(ii) Linking 3 layers

Keep two layers made in step (i) in staggered position as shown in the picture. Now link them using large (long)linkers as shown with dotted lines.

Now keep the third layer above the upper layer in staggered position. It should match with the lower layer and link it with the upper layer with a large (long) linker. Thus alternate layers would overlap. It is possible to move different layers little bit parallel



to each other to understand how different layers in graphite can slide and this makes it a slippery material.

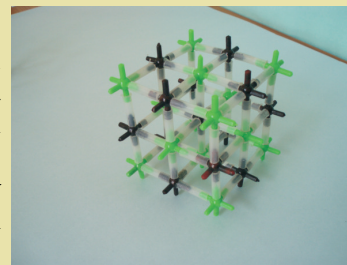
## 2. Sodium Chloride, NaCl

*Items required*

- (i) Six-prong brown atom (Na) - 14 pc
- (ii) Six-prong green atoms (Cl) - 13 pc
- (iii) Small linkers

*How to make*

- (a) Make two square layers by linking brown and green atoms alternately. Keep brown atoms at corners as shown in the picture. Call them layers 1 and 3.
- (b) Make a layer similar to the above but now taking green atoms at corners as shown in picture.
- (c) Keep layer 1 at the bottom. Place layer 2 above it such that both the layers overlap each other. Now the green atoms of layer 2 would be above the brown atoms of layer 1 and vice-versa. Then, link the two layers with the help of small linkers.
- (d) Now keep layer 3 above layer 2 as given above and link them with small linkers. This would make a small portion of NaCl crystal network.

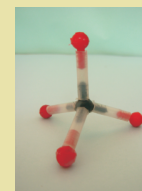


### 3. Silicates

#### (A) $\text{SiO}_4^{4-}$ unit

*Items required*

- (i) Four-prong black atom (Si) - 1 pc
- (ii) One-prong red atom (O) - 4 pc
- (iii) Small linkers- 4 pc





*How to make*

Attach four one-prong red atom (O) to four prong black atom(Si) by small linkers.

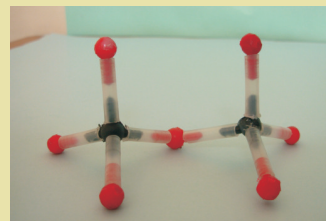
**(B)  $\text{Si}_2\text{O}_7^{6-}$ , unit**

*Items required*

- (i) Four-prong black atom (Si) - 2 pc
- (ii) One-prong red atom (O) - 6 pc
- (iii) Two-prong (linear) red atom (O) - 1 pc
- (iv) Small linkers - 8 pc

*How to make*

Take two-prong (linear) red atom (O) and connect two four prong black atoms (Si) with small linkers. Now connect six one-prong red atoms (O) with the two (Si) atoms.



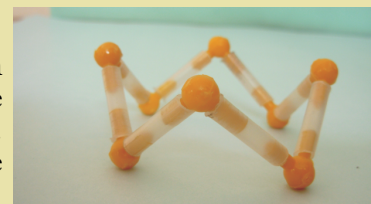
**4. Sulphur,  $\text{S}_8$**

*Items required*

- (i) Two-prong bent red atoms (S) - 8 pc
- (ii) Small linkers - 8 pc

*How to make*

Connect two-prong (bent) red atoms (S) with one another keeping the prongs of alternate atoms in pointing upwards and downward. These would connect to form a crown like structure of  $S_8$ .



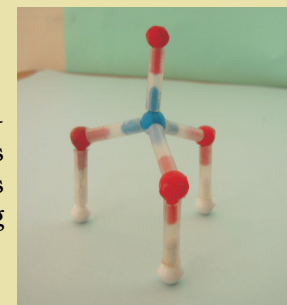
**5. Oxyacids of phosphorous,  $H_3PO_4$  unit**

*Items required*

- (i) Four-prong brown atoms (P) - 1 pc
- (ii) Two-prong red atoms (O) - 3 pc
- (iii) One-prong red atom (O) - 1 pc
- (iv) One-prong white atoms (H) - 3 pc
- (v) Small linkers - 7 pc

*How to make*

Take four-prong brown atom (P) and link one one-prong red atom (O) and three two prong red atoms (O) to it. Now connect three one-prong white atoms (H) to the second-prong of each of the two-prong red atoms.



### III. STRUCTURE OF ORGANIC MOLECULES

#### 1. Saturated Organic Compound

##### (A) Methane, $\text{CH}_4$

*Items required and How to make*

As given earlier under structure of simple molecules.



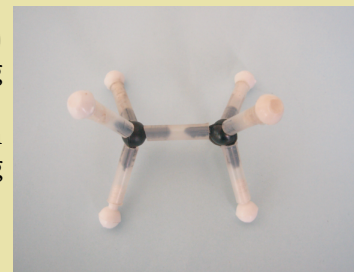
##### (B) Ethane, $\text{C}_2\text{H}_6$

*Items required*

- (i) Four-prong black atoms (C) - 2 pc
- (ii) One-prong white atoms - 6 pc
- (iii) Small linkers - 7 pc

*How to make*

Connect two four-prong black atoms (C) by a small linker. Now connect one-prong white atom (H) to each free prongs of 1 C atoms. The two carbon atoms can be rotated with respect to other about the sigma bond linking them.



## 2. Unsaturated organic compounds:

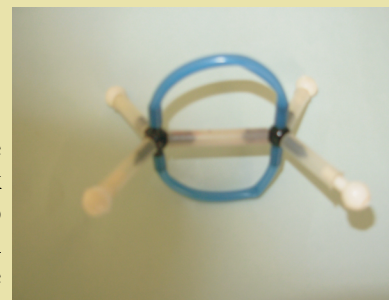
### (A) Ethene, $C_2H_4$

*Items required*

- (i) Five-prong black atoms (C) - 2 pc
- (ii) One-prong white atoms (H) - 4 pc
- (iii) Small linkers - 5 pc
- (iv) Sleeves (blue) - 2 pc

*How to make*

Link one-prong out of the three in the same plane of each of the two five-prong black atoms (C) by a small linkers. Attach two one-prong white atoms (H) to each (C) on the remaining prongs which are in the same plane as the ones interconnecting the two (C) atoms. This would leave two prongs on each (C) atom perpendicular to the plane of the molecule. Rotate the (C) atoms about the linker linking them till all the H atoms come in the same plane. Connect the two prongs above the common plane with a blue sleeve and the two below the plane with another blue sleeve. These sleeves represent the pi-electrons of the pi bond between two carbon atoms. It may be noted that now the rotation of carbon atoms about the double bond is not possible.



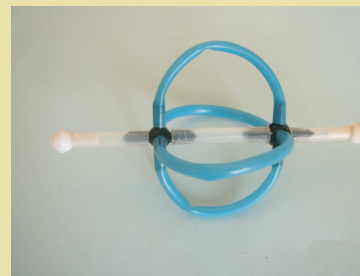
**(B) Ethyne, C<sub>2</sub>H<sub>2</sub>**

*Items required*

- (i) Six-prong black atoms (C) - 2 pc
- (ii) One-prong white atoms (H) - 2 pc
- (iii) Small linkers - 3 pc
- (iv) Sleeves(blue) - 4 pc

*How to make*

Link two six-prong black atoms (C) by a small linker. Now connect one one-prong white atom (H) to each of the (C) atoms such that all the four atoms are in straight line. These linkers represent the sigma bond in the ethyne molecule. Each (C) atom is left with four prongs which are mutually perpendicular and also are perpendicular to the main sigma bond skelton of the molecule. Connect these prongs in pairs, one from each (C) atom by blue sleeve. The four sleeve represent the pie electrons of two pie bonds.



**(C) Benzene, C<sub>6</sub>H<sub>6</sub>**

*Items required*

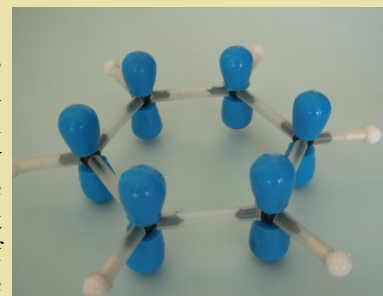
- (i) Five-prong black atoms (C) - 6 pc
- (ii) One-prong white atoms (H) - 6 pc
- (iii) Orbital lobes - 12 pc

(iv) Small linkers - 12 pc

(v) Sleeves - 6 pc

*How to make*

Each of the five-prong black (C) atom has three prongs in one plane and two in perpendicular upward and downward direction. Make the six membered ring by linking. The six (C) atom using two of the three prongs in the same plane. Connect one one-prong white (H) atom to each of these on the third prong. This would make the basic sigma bond skeleton of Benzene molecule.



Each (C) atom has two prongs, one pointing upward and other downwards. pi bonds can be depicted in one of the two following ways :

- Connect the orbital lobes to all the prongs on the (C) atoms. These represent the lobes of p-orbitals above and below the ring, which overlap to make the benzene molecule.
- Connect the prongs on adjacent atoms by blue sleeves as shown in picture. The three pair of sleeves above and below alternate sigma bonds between atoms represent the pi electrons of the pi bond between them.

### 3. Organic molecules containing O and H containing functional groups

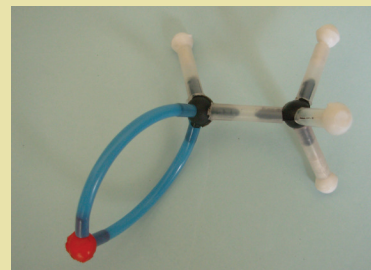
#### (A) Aldehyde : Ethanal, $\text{CH}_3\text{CHO}$

##### Items required

- (i) Four-prong black atoms (C) - 2 pc
- (ii) One-prong white atoms (H) - 4 pc
- (iii) Two-prong (bent) red atom (O) - 1 pc
- (iv) Small linkers - 5 pc
- (v) Sleeve(blue) - 2 pc

##### How to make

Link two four-prong black to (C) to atoms to each other and attach three one-prong white (H) atoms to one of these and one to the other (C) atom, as in case of ethane. Link the two prong (bent) red (O) atom to the latter (C) atom by two blue sleeves. These sleeves represent the double bond between (C) and (O) atom.



#### (B) Ketone : Propanone, $\text{CH}_3\text{COCH}_3$

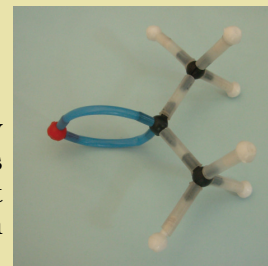
##### Items required

- (i) Four-prong black atom (C) - 3 pc
- (ii) One-prong white atoms (H) - 6 pc
- (iii) Two-prong(bent) red atom (O) - 1 pc

- (iv) Small linkers - 8 pc
- (v) Sleeves(blue) - 2 pc

*How to make*

Connect the three four-prong black (C) atoms by small linkers. Attach three one-prong white (H) atoms to each of the two (C) atoms at the ends. Now connect the two-prong (bent) red (O) atom to the (C) atom in the middle by two blue sleeves.



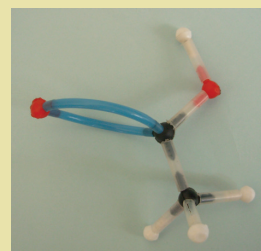
**(C) Carboxylic acid : Ethanoic acid,  $\text{CH}_3-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH}$**

*Items required*

- (i) Four-prong black atoms (C) - 2 pc
- (ii) One-prong white atoms (H) - 4 pc
- (iii) Two-prong(bent)red atoms (O) - 2 pc
- (iv) Small linkers - 5 pc
- (v) Sleeves(blue) - 2 pc

*How to make*

Connect the two four-prong black (C) atoms by a small linkers. Attach three one-prong white (H) atoms to one of the (C) atoms .Attach one two-





prong red(O) atom to two prongs of the second (C) atom with blue sleeves as in case of propane. Connect one prong of the other (O) atom to the second (C) atom. Now connect the remaining H atom to the second prong of this (O) atom.

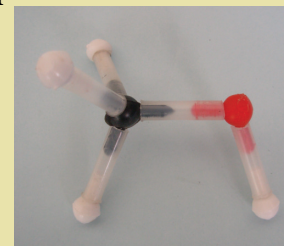
**(D) Alcohols : Methanol,  $\text{CH}_3\text{OH}$**

*Items required*

- (i) Four-prong black atom (C) - 1 pc
- (ii) One-prong white atom (H) - 4 pc
- (iii) Two-prong(bent) red atom (O) - 1 pc
- (iv) Small linkers - 5 pc

*How to make*

Attach three one-prong white (H) atoms to the four-prong black (C) atom. Attach the two-prong (bent) red (O) atom to the remaining prong of (C) atom. Now attach the remaining (H) atom to the second prong of (O) atom to complete the construction.



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**4. Organic molecules with functional group containing N**

**(A) Amines : Methamine,  $\text{CH}_3\text{NH}_2$**

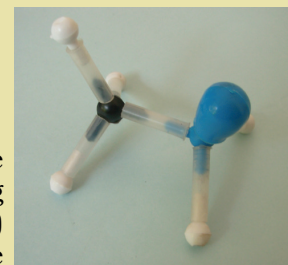
*Items required*

- (i) Four-prong black atom (C) - 1 pc
- (ii) One-prong white atom (H) - 5 pc

- (iii) Four-prong blue atom (N) - 1 pc
- (iv) Orbital lobe - 1 pc
- (v) Small linkers - 6 pc

*How to make*

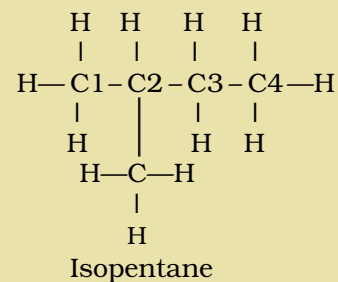
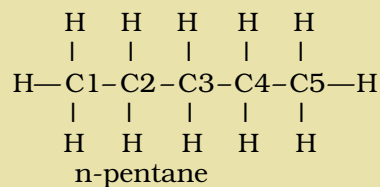
Connect the four-prong black (C) atom and the four-prong blue (N) atom. Attach three one-prong white (H) atoms to the (C) atoms and two the (N) atom. Attach the blue orbital lobe (representing the lone pair of electrons) to the (N) atom.



#### IV. ISOMERISM IN ORGANIC MOLECULES

##### 1. Chain Isomers : Pentane

Chain isomerism can be shown in pentane molecule. Different chain isomers are shown below.



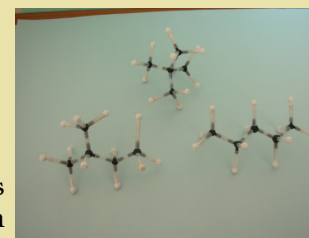
##### *Items required*

- (i) Four-prong black atoms (C) - 5 pc
- (ii) One-prong white atoms (H) - 12 pc
- (iii) Small linkers - 16 pc

##### *How to make*

- (a) n-Pentane

Interconnect the five four-prong black (C) atoms by small linkers. Attach one one-prong white atom



to each of the remaining prongs of (C) atoms. This would result in the construction.

(b) Isopentane

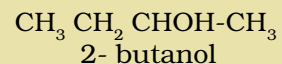
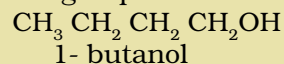
It can be made by modifying the model of n-pentane made earlier. Disconnect one of the end (C) atom with three (H) atoms attached to it. ( $\text{CH}_3$  group) from the next (C) atom which becomes the end carbon atom (say no.1) Remove one (H) atom from the next (C) atom (no.2) and replace by the  $\text{CH}_3$  group. Attach (H) atom to the end carbon atom (no.1) at the prong from where  $\text{CH}_3$  group was removed to complete the construction.

(c) Neo -pentane

It can be made by modifying the model of isopentane made earlier. From carbon atom no.2, disconnect (H) and  $\text{CH}_2\text{CH}_3$  groups. Disconnect the two (C) atoms of  $\text{CH}_2\text{CH}_3$  and attach the (H) atom to  $\text{CH}_2$  group. This would give two  $\text{CH}_3$  groups. Attach each of these to the two prongs of the carbon atom from which (H) and  $\text{C}_2\text{H}_5$  had been removed. This would complete the construction of neopentane.

## 2. Position isomerism : Butanol

Position isomerism can be shown in butanol by changing the position of OH group

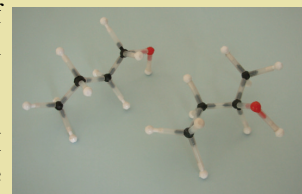


*Items required*

- (i) Four-prong black atoms (C) - 8 pc
- (ii) One -prong white atoms (H) - 20 pc
- (iii) Two-prong(bent) red atoms (O) - 2 pc
- (iv) Small linkers - 28 pc

*How to make*

Connect one one-prong white (H) atom to each of the two-prong(bent) red (O) atoms. This would make 2 OH groups. Link four-prong black (C) atoms to make one chain and remaining 4 (C) atoms to make the second chain. Attach one OH to the end (C) atom(no.1) of one chain and the other OH group to one of the middle (C) atoms(no.2) of the other chain. Attach one prong (H) atom to each of the vacant prongs of (C) atoms in both the chain. The model with OH group on (C) atom no.1 (end atom) represent 1-butanol and the other one 2-butanol.



**3. Functional group isomerism**

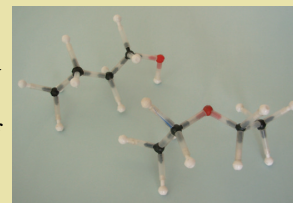
Functional group isomerism can be shown with the help of models of two molecules butanol and diethyl ether both with the same molecular formula  $C_4H_{10}O$ .

*Items required*

- (i) Four prong black atoms (C) - 4 pc
- (ii) One-prong white atoms (H) - 20 pc
- (iii) Two-prong (bent) red atoms (O) - 2 pc
- (iv) Small linkers - 28 pc

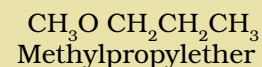
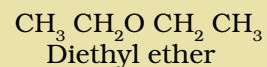
*How to make*

- (a) Butanol - Make 1-butanol as given earlier.
- (b) Diethylether - Construct two  $C_2H_5$  groups by connecting two four prong black (C) atom each and attaching five one prong white (H) atoms to each of these. Now connect the two  $C_2H_5$  groups to the two prong (bent) red (O) atom. This completes the model of diethyl ether.



**4. Metamerism**

Metamerism can be shown with the help of models diethyl ether and methyl propyl ether both with the molecular formula  $C_4H_{10}O$ .

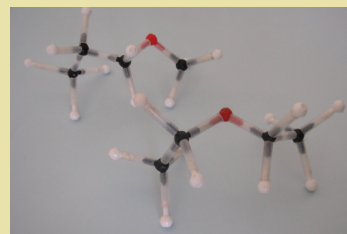


*Items required*

Same as in the last activity i.e. Functional group isomerism.

*How to make*

- (a) Diethylether – As given earlier
- (b) Methylpropylether-Instead of two  $C_2H_5$  groups, make one  $CH_3$  group and one  $C_3H_7$  group and connect them to the prongs of the red (O) atom.



## 5. Geometrical isomerism

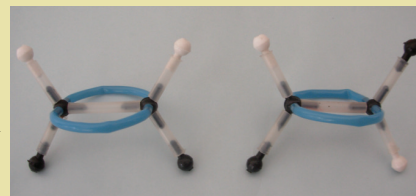
Geometrical isomerism can be shown by the models of cis and trans 2-butene.

*Items required*

- (i) Five-prong black atoms (C) - 4 pc
- (ii) One-prong white atoms (H) - 16 pc
- (iii) One-prong black atoms - 4 pc
- (iv) Small linkers - 22 pc
- (v) Sleeves blue - 4 pc

*How to make*

Make two basic skeleton of two five prong black (C) atoms as shown using the three prongs in the same plane. Now attach 2 one-prong white (H) atoms and

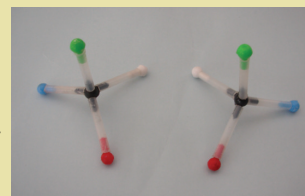


2 one-prong black (representing  $\text{CH}_3$  group). All the atoms should be in the same plane.

Now connect the two prongs on each five-prong (C) atom by blue sleeves to show the double bonds as shown in the picture. This would stop the rotation of carbon atoms about double bonds and fix the relative position of groups attached. (One prong black atoms representing  $\text{CH}_3$  group can be replaced by actual  $\text{CH}_3$  groups as made in earlier models)

#### 6. Enantiomorphism : Lactic Acid

Enantiomorphism is the phenomenon of existence of a substance in two crystallisation forms, one being a mirror image of the other. It occurs when the molecules of the substance are asymmetric (i.e. all four groups attached to a particular carbon atom are different). The two forms are mirror image of each other. The two forms are enantiomers or optical isomers. This phenomenon can be shown with the help of models of enantiomers of lactic acid  $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$  as shown below.



##### *Items Required*

- (i) Four-prong black atoms (C) - 2 pc
- (ii) One-prong white atoms (H) - 2 pc



- (iii) One-prong red atoms (OH) - 2 pc
- (iv) One-prong black atoms (COOH) - 2 pc
- (v) One-prong blue atoms (CH<sub>3</sub>) - 2pc
- (vi) Small linkers-8 pc

*How to make*

Simple models of enantiomers of lactic acid can be made by loosing or choosing one prong atoms of different colours to represent different groups as given above. Attach the four one-prong atoms of different colours to one of the four - prong black (C) atoms. Carefully attach the second set of four one - prong atoms of different colours such that this molecule is the mirror image of the earlier one. The two molecules are enantiomers(optical isomers).

More complete models can be prepared by actually constructing the groups attached to the central (C) atom, besides white (H) atom, namely OH, CH<sub>3</sub> and COOH groups. However the concept of enantiomorphism can be understood even by the simple models.

## V. COORDINATION CHEMISTRY

### 1. Cis-trans Isomers : $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$

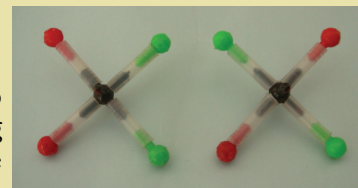
Many complexes also show the geometrical isomerism and form cis and trans isomers.  $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$  is one such coordination compound.

#### *Items required*

- (i) Six -prong brown atoms (Pt) - 2 pc
- (ii) One-prong blue atoms ( $\text{NH}_3$  group) - 4 pc
- (iii) One-prong green atoms (Cl) - 4 pc
- (iv) Small linkers - 8 pc

#### *How to make*

To each six-prong brown Pt atom attach two one-prong blue  $\text{NH}_3$  groups and two one-prong green  $\text{NH}_3$  groups. These groups should be attached only to the four prongs which are in the same plane to obtain square-planer molecule. In one molecule blue and green groups should be attached alternately so that two blue  $\text{NH}_3$  groups occupy diagonally opposite positions and so do the green Cl groups. This is trans-isomers. In the other molecules attach two blue  $\text{NH}_3$  groups on neighbouring prongs and two green Cl groups on the other two neighbouring position. This is cis-isomer.



## 2. Facial Meridional $\text{Co}(\text{NH}_3)_4\text{Cl}_2$

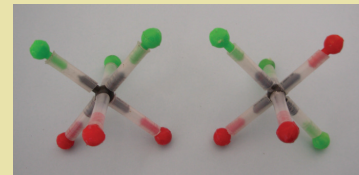
This is another type of geometrical isomerism shown by octahedral coordination compounds of the type  $[\text{Ma}_3\text{b}_3]$  like  $[\text{Co}(\text{NH}_3)_3(\text{NO}_2)_3]$  facial (fac) isomer is formed when three donor atoms of the same ligand occupy two adjacent positions on the corner of square and one of the two remaining positions on the meridian such that they occupy corners of one face of the octahedron (shown in red in the figure). When the three donor atoms of the same ligand occupy adjacent positions around the meridian (shown in red) i.e. the three corners of the square, the isomer is called meridional (mer) isomer as shown below.

### Items required

- (i) Six-prong brown atoms (Co) - 2 pc
- (ii) One-prong green atoms ( $\text{NH}_3$ ) - 6 pc
- (iii) One-prong red atoms ( $\text{NO}_2$ ) - 6 pc
- (iv) Small linkers - 12 pc

### How to make

Hold one six-prong brown (Co) atom such that four prongs in the same plane lie on horizontal plane and the remaining two are vertically aligned. Attach three one-prong red ( $\text{NO}_2$ ) groups as shown in the figure (facial isomer i.e. two on the adjacent corners of the square and one one-prong which is below the square). These three ( $\text{NO}_2$ ) groups occupy the corners



of one face of the octahedron formed by joining the six corners. Now attach three one-prong green  $\text{NH}_3$  group to remaining prong of Co atom to make the fac-isomer. To make mer-isomer repeat the procedure, but attach the three red  $\text{NO}_2$  groups to three of the four prongs which lie on the same plane and the three green one-prong  $\text{NH}_3$  groups on the remaining prongs of the six-prong brown Co atom.

### 3. Optical isomers, $[\text{Co}(\text{en})_3]^{3+}$

Coordination compounds also show optical isomerism especially octahedral complexes involving didentate legands like  $[\text{Co}(\text{en})_3]^{3+}$  as shown below

#### *Items required*

- (i) Six-prong brown atoms (Co) - 2 pc
- (ii) Sleeves (blue)(en) - 6 pc

#### *How to make*

Take one six-prong brown Co atom and hold it so that the four of its planer prongs are on a horizontal plane and out of the remaining two one is pointing upwards and the other downwards. Connect two adjacent prongs on the horizontal plane by one sleeve . Each end of the sleeve represents one donor atom (N in this case) of the didentate legand ethane-1,2-diamine (abbreviated as en). Connect which atom's prong on Co atom pointing upwards with the

one on the horizontal plane with second sleeve. Now connect the prong on Co atom that is pointing downwards with the last free prong on the horizontal plane with the third sleeve (en). Now take the second six prong brown Co atom and connect its 3 pairs of prongs with three sleeves (en) such that it becomes the mirror image of the first one.

#### 4. Confirmation

Confirmation of a molecule is the spatial arrangement of its constituent atoms which can be converted into another confirmation by rotation about a single bond in a molecule. Two common types of confirmations can be seen with the help of the following models.

##### (i) **Chair and boat forms : Cyclohexane, $C_6H_{12}$**

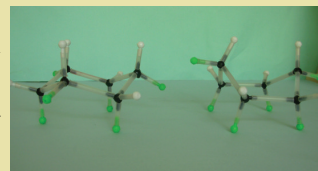
Cyclohexane shows chair and boat confirmations as shown below. In chair form the carbon atoms number 2,3,4 and 5 lie in a plane and the 1 and 4 lie on opposite sides of the plane. In the boat confirmation the carbon atoms 1 and 4 lie on the same side of the plane.

##### *Items required*

- (i) Four-prong black atoms (C) - 12 pc
- (ii) One-prong white atoms (H) - 24 pc
- (iii) Small linkers - 36 pc

*How to make*

Link six four-prong black C atoms by small linkers. Now attach 12 one-prong white H atoms to the carbon atoms (2 on each C) to make a molecule of  $C_6H_{12}$ . Now try to adjust the shape to chair confirmation. Similarly make second molecule of cyclohexane  $C_6H_{12}$ . Now adjust its shape to boat confirmation.



**(ii) Eclipsed and staggered conformations : Ethane,  $C_2H_6$**

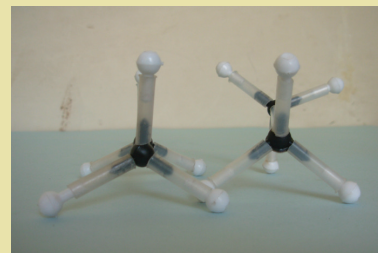
Complete rotation of atoms is possible around a single bond. This can give rise to infinite numbers of conformations. In ethane molecule  $H_3C-CH_3$ , one methyl group can rotate relative to the other. Two important conformations are eclipsed and staggered. In eclipsed confirmation, when viewed along the C-C bond, the three C-H bonds one methyl group exactly align with those in the other methyl group. This is eclipsed confirmation. In the other, the C-H bonds on one methyl group bisect the angle between two C-H bonds on the other as shown below.

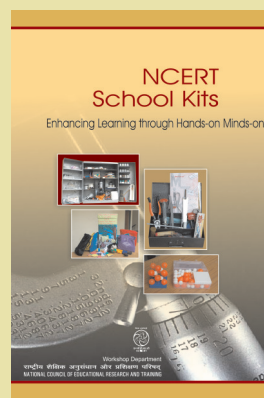
*Items required*

- (i) Four-prong black atoms (C) - 4 pc
- (ii) One-prong white atoms (H) - 12 pc
- (iii) Small linkers - 14 pc

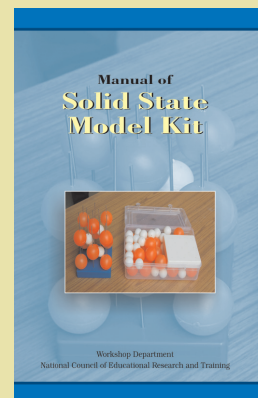
*How to make*

Make two models of ethane molecule as describe earlier. Now rotate methyl groups of one of these to bring the C-H bonds of one methyl group exactly in alignment with the C-H bonds in the other methyl (see figure). This would be the model showing eclipsed confirmation. Now rotate the two methyl groups of the second model such that C-H bonds of one bisect the angles between C-H bonds of the other as shown in the figure. This model would show the staggered confirmation.





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