

An explanation sheet for making

# Straw Molecular Model

2nd version



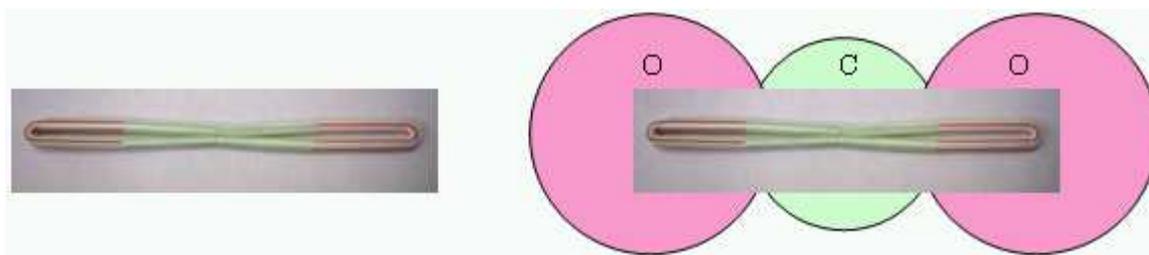
## Materials and tools

- 5mm diameter plastic straws and 6mm diameter plastic straws
- A ruler
- A (good) pair of scissors
- Proper chemistry text book

## Introduction

Straw molecular model is an educational material sample which is affordable and helpful to understand skeleton structure of molecules.

Each atom is represented by one straw or a combination of several straws and these straws are connected with connector straws (joint) in order to make a molecular model. For example when you make a carbon dioxide model, first of all you should combine 4 pale green straws which represent four connectable arms of a carbon atom. Then cut out two straws which have flexible part in the middle of them. Fold them parallel then they represent oxygen atoms which have two connective arms. Connect one oxygen straw and carbon with two connectors after that connect another oxygen and carbon again. You can see straw carbon dioxide molecular model.



General commercial molecular models have plastic spheres which represent atoms. But for this straw model it is impossible, therefore please imagine that the carbon atom exists in the middle of the crossing of pale green straws and flexible parts of the purple straws are the centres of oxygen atoms.

Nevertheless this low cost straw model can show double and triple bonds as well, so we can use this material from upper basic school level to secondary school level.

### Covalent radii

When making molecular model it is important to express relative distance between atoms as accurate as possible. This explanation sheet basically uses covalent radii (table 1) as distances between atoms. Due to the types of the straws we can buy, I multiplied  $6.4 \times 10^8$  or  $4.4 \times 10^8$  on each covalent radius and made length of straws for big models and small models. If you want to make much accurate models, I recommend using the bond lengths shown on table 2 and adjust lengths of straws.

Table 1. Some Covalent radii

Element	H	C	N	O	F	Cl	Br	I	
Covalent radius (pm= $10^{-12}$ m)	37	77	74	73	71	99	114	133	
Length of straw (mm)	big model	24	49	48	47	46	64	74	86
	small model	16	34	32	32	31	44	50	59

Table 2. Bond length

Bond	Comment	Bond length (pm= $10^{-12}$ m)	Length of straw for one atom (mm)	
			big model	small model
H-H	In H <sub>2</sub>	74	24	16
H-Cl	In HCl	127	*	*
H-O	In H <sub>2</sub> O	96	*	*
Cl-Cl	In Cl <sub>2</sub>	199	64	44
Br-Br	In Br <sub>2</sub>	228	73	50
I-I	In I <sub>2</sub>	267	85	59
N-N	In N <sub>2</sub> H <sub>4</sub>	147	47	32
N≡N	In N <sub>2</sub>	110	35	24
O-O	In H <sub>2</sub> O <sub>2</sub>	128	41	28
O=O	In O <sub>2</sub>	121	39	27
C-H	Organics	108	*	*
C-Cl	Halogenoalkane	177	*	*
C-O	Organic OH groups	143	*	*
C=O	Aldehydes and ketones	122	*	*
C-C	Organics	154	49	34
C=C	In C <sub>2</sub> H <sub>4</sub>	134	43	29
C≡C	In C <sub>2</sub> H <sub>2</sub>	121	39	27
C-C,C=C (benzene)	In benzene C <sub>6</sub> H <sub>6</sub> *2	140	45	31
C-N	Amines	147	*	*
C≡N	Nitriles	116	*	*

\* adjust the length properly (by cutting the straws or making overlapping)

\*2 check "how to make a benzene model"

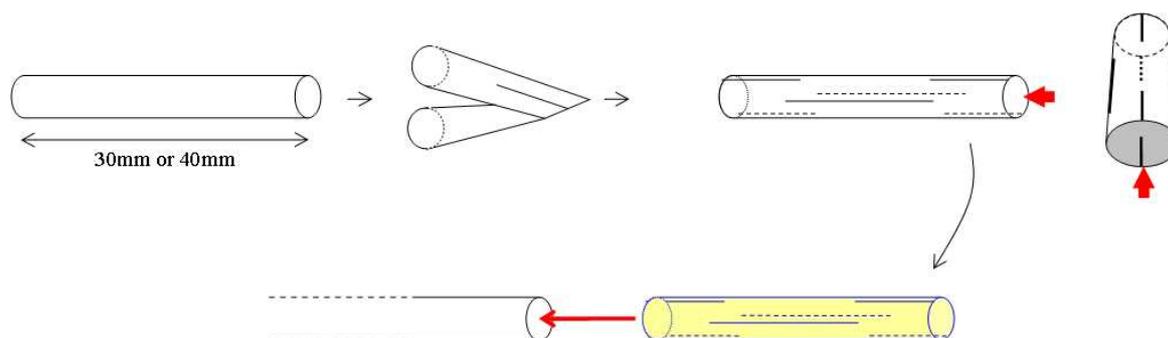
### Colour of straws and atoms and their number of connective arms (valency)

For the samples of molecular models shown below the following straws were used: pale green straws as carbon (C) atoms, orange straws as hydrogen (H) atoms, purple straws as oxygen (O) atoms and yellow straws as nitrogen (N) atoms. I used white or pale colour straws as connector straws. A combination of elements, number of connective arms and colours of straw are shown below.

Table 4. Combinations of straw and element

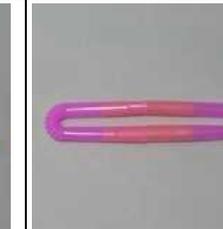
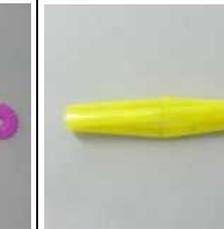
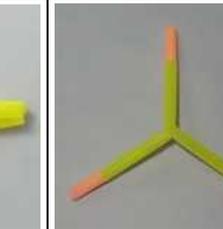
Element	H	C	N	O
number of arm(s)	1	4	3	2
colour of straw	orange	pale green	yellow	purple
Photo				

### How to make a connector (joint)



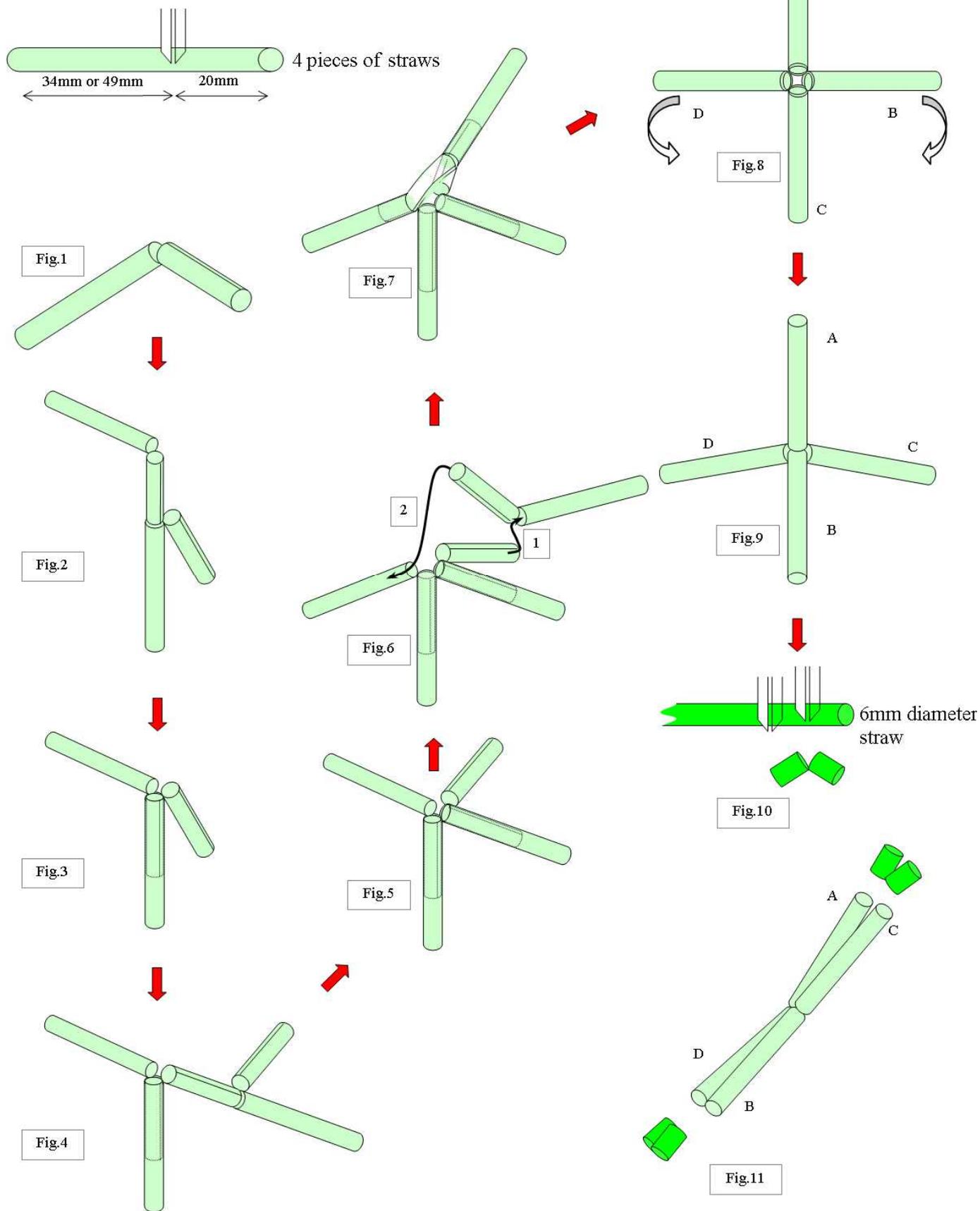
Cut out 40mm (or 30mm for small size models) white or pale colour straw piece. Fold the piece and make a cut like the folded side picture above. Straighten the straw and make short cut on both ends which are orthogonal to previous slits. You can connect open straw ends with these connectors (joints) without any glue or adhesive tapes.

### Samples of small molecules

H <sub>2</sub>	H <sub>2</sub> O	O <sub>2</sub>	N <sub>2</sub>	NH <sub>3</sub>
				

### Example 1: Making a carbon (C) atom and a methane model

Follow the illustrated instruction in order to assemble carbon atom model which has  $sp^3$  hybrid orbital



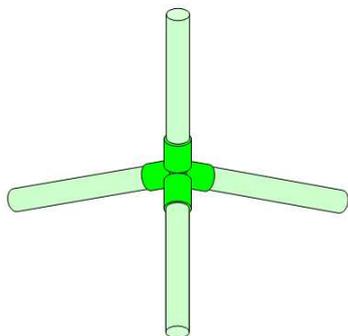


Fig. 12

Finished  $sp^3$  carbon atom model

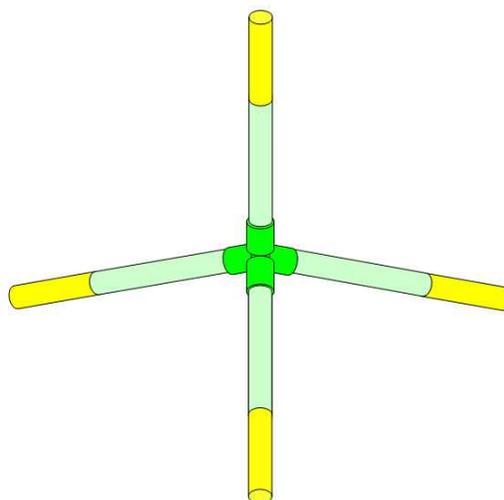


Fig. 13

Methane model ( $CH_4$ )

If you want to make a methane model, prepare four straw pieces (24mm long pieces for big models, 16mm long pieces for small models) which represent hydrogen atoms and four connectors (joints).

You can also connect carbon atom models. The following figures show how to make an ethane model.

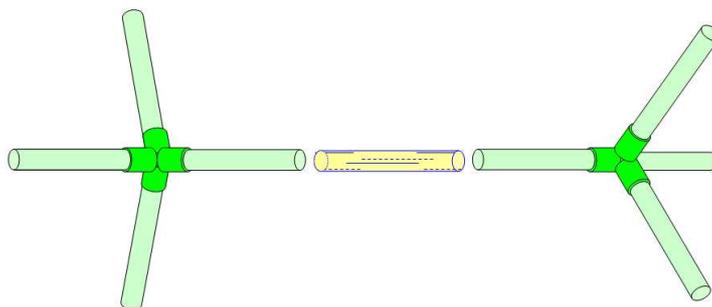


Fig. 14

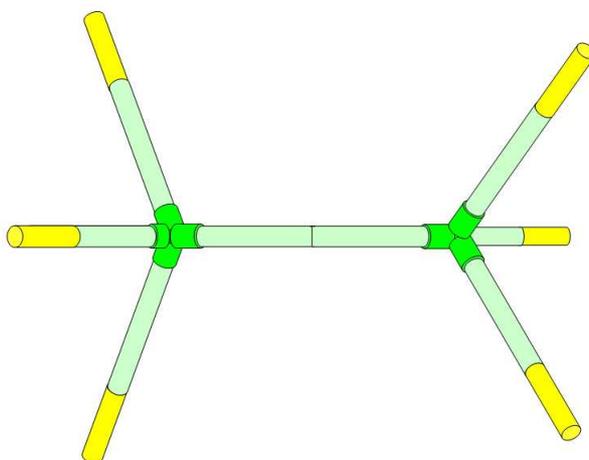


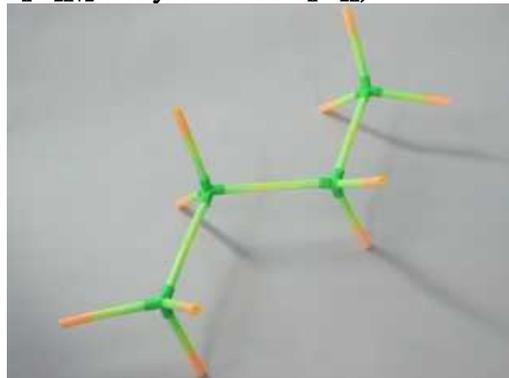
Fig. 15

Ethane model ( $CH_3-CH_3$ )

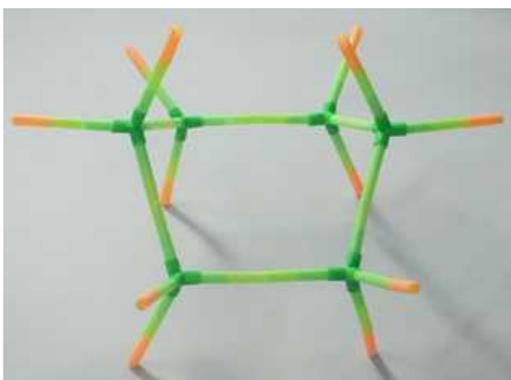
**Example 2: Application of the methane model (Alkane  $C_nH_{2n+2}$  & Cycloalkane  $C_nH_{2n}$ )**



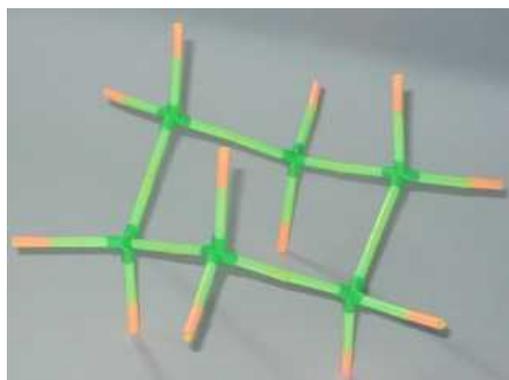
Propane ( $C_3H_8$ ,  $CH_3-CH_2-CH_3$ )



Butane ( $C_4H_{10}$ ,  $CH_3-CH_2-CH_2-CH_3$ )



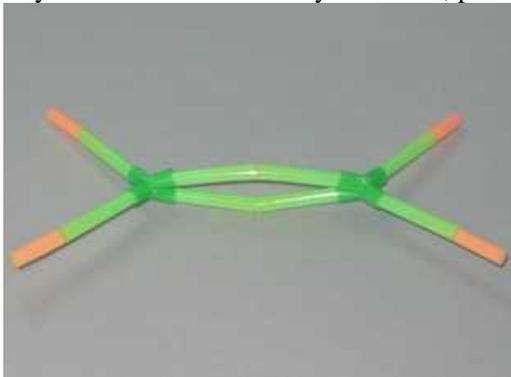
Cyclohexane ( $C_6H_{12}$ ) Boat



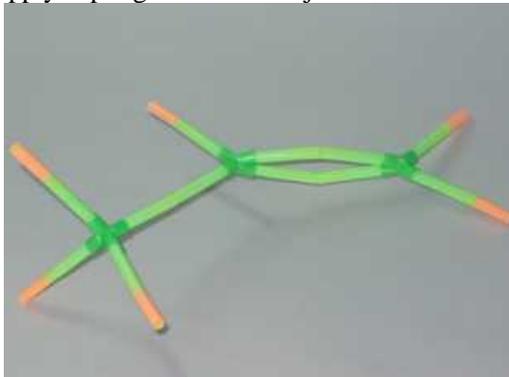
Cyclohexane ( $C_6H_{12}$ ) Chair

**Example 3: Alkene  $C_nH_{2n}$**

When you make alkene and alkyne models, please do not apply super glue on the conjunction of C straws!

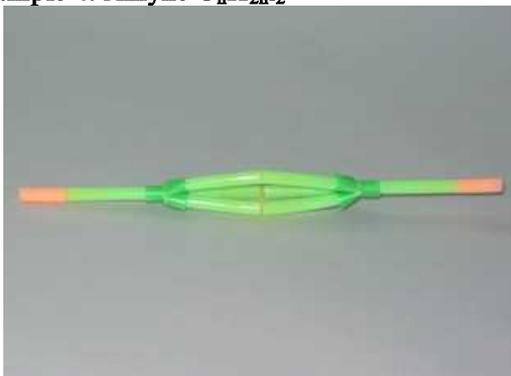


Ethylene ( $C_2H_4$ ,  $CH_2=CH_2$ )

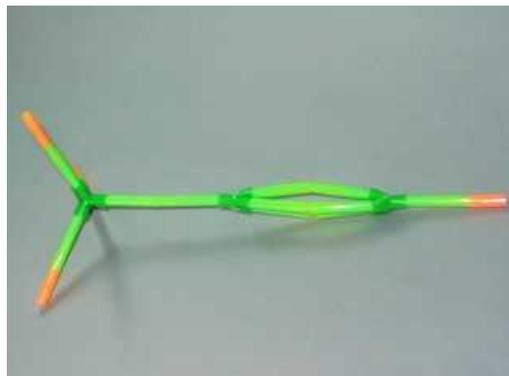


Propylene ( $C_3H_6$ ,  $CH_3-CH=CH_2$ )

**Example 4: Alkyne  $C_nH_{2n-2}$**



Acetylene (Ethyne) ( $C_2H_2$ ,  $CH\equiv CH$ )

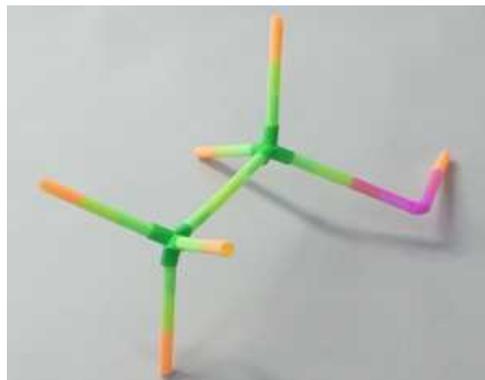


Propyne ( $C_3H_4$ ,  $H_3C-C\equiv CH$ )

**Example 5: Alcohol R-OH**



Methyl alcohol ( $\text{CH}_3\text{OH}$ )



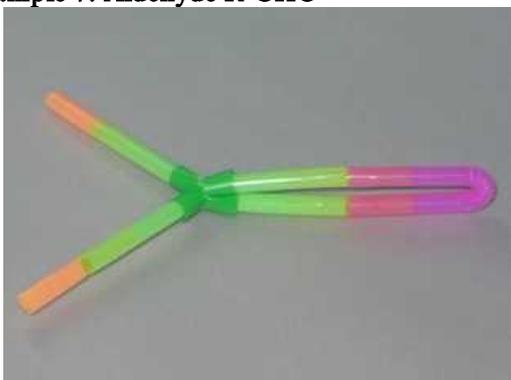
Ethyl alcohol ( $\text{CH}_3\text{CH}_2\text{OH}$ )

**Example 6: Ether R-O-R'**

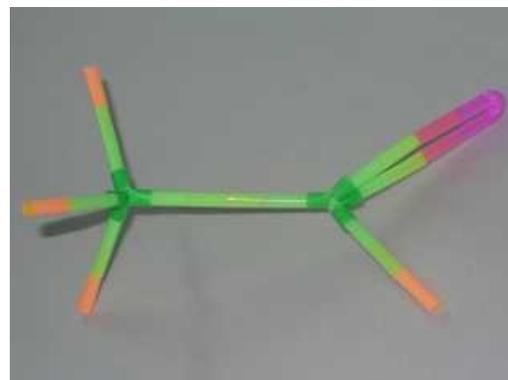


Diethyl ether ( $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$ )

**Example 7: Aldehyde R-CHO**



Formaldehyde ( $\text{HCHO}$ )

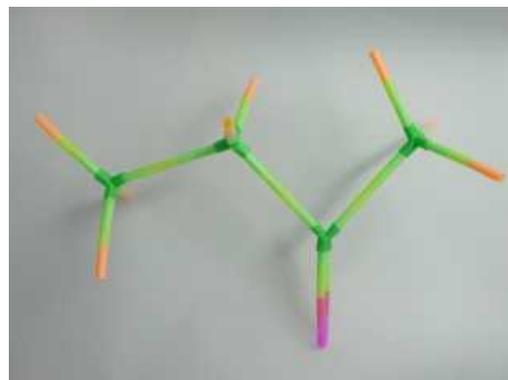


Acetaldehyde ( $\text{CH}_3\text{CHO}$ )

**Example 8: Ketone R-CO-R'**



Acetone ( $\text{CH}_3\text{COCH}_3$ )

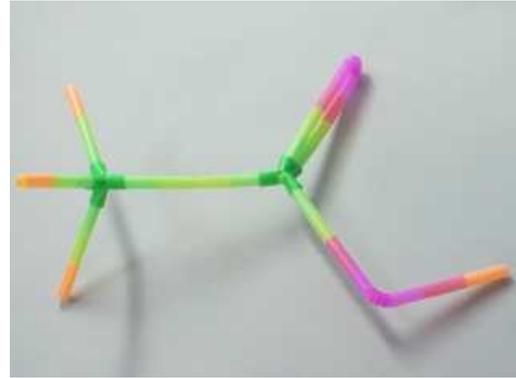


Ethyl methyl ketone ( $\text{CH}_3\text{CH}_2\text{COCH}_3$ )

**Example 9: Carboxylic acid R-COOH**

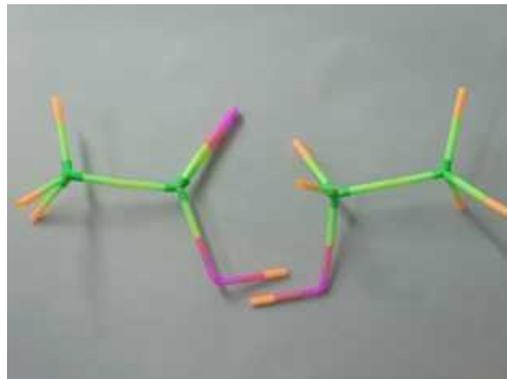


Formic acid ( $\text{HCOOH}$ )

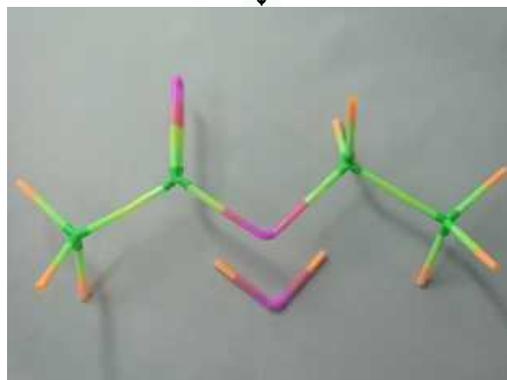


Acetic acid ( $\text{CH}_3\text{COOH}$ )

**Example 10: Ester R-COO-R'**



Carboxylic acid + Alcohol  
example: Acetic acid ( $\text{CH}_3\text{COOH}$ ) + Ethyl alcohol ( $\text{CH}_3\text{CH}_2\text{OH}$ )



Ethyl acetate ( $\text{CH}_3\text{COOCH}_2\text{CH}_3$ ) + Water ( $\text{H}_2\text{O}$ )

### Example 11: How to make a benzene model

1 Prepare the following straws

Atom	Related Bond	Actual length ( $\text{pm} = 10^{-12}\text{m}$ )	Length of straw for a big model (mm)	Length of straw for a small model (mm)	Number of straws
C	C-C bond	140	90+20+20	62+20+20	6
	C-H bond	110	45+20	31+20	6
H			24	16	6
Connector			40	26	6

Each carbon atom of benzene molecule is connected by  $sp^2$  hybrid orbital, therefore carbon atoms of this benzene model have three connective arms.



2 Make two transversal slit on C-C bond straw (below) on each opposite side and one transversal slit on C-H bond straw. Make a longitudinal slit on each 20mm part of the straw.



3 Insert a slit side of a C-H bond straw into a C-C bond straw's



4 Assemble straws along pictures 4-9.



5



6



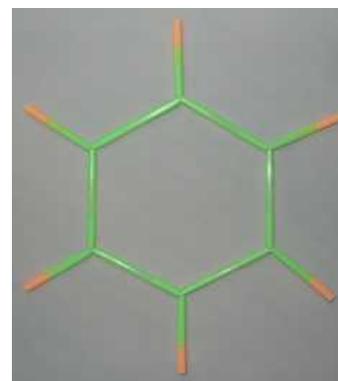
7



8 Half of the carbon skeleton of benzene model is finished.

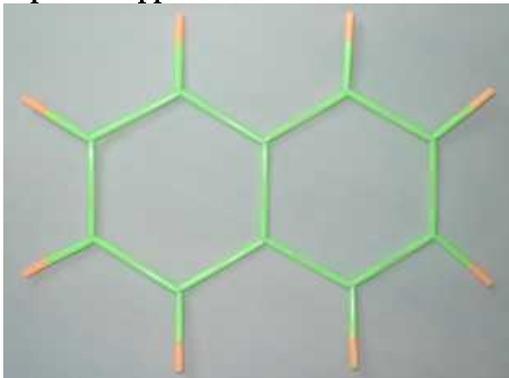


9 Finished carbon skeleton of benzene model.



10 Insert connectors into C-H bond straws. After that put H atom straws to the connectors.

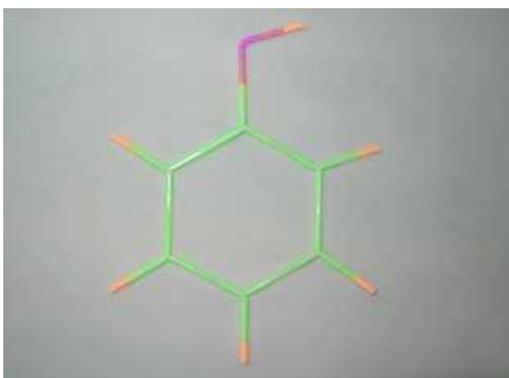
**Example 12: Application of the benzene model**



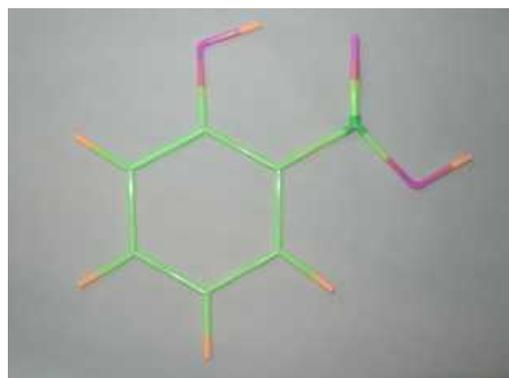
Naphthalene



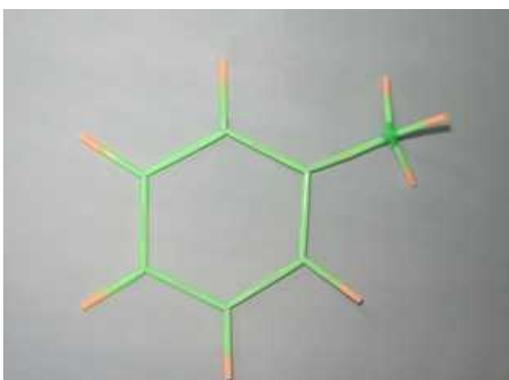
Benzoic Acid  $C_6H_5COOH$



Phenol  $C_6H_5OH$



Salicylic Acid  $C_6H_4(OH)(COOH)$



Toluene  $C_6H_5CH_3$



o-Cresol  $C_6H_4(CH_3)OH$



m-Xylene  $C_6H_4(CH_3)_2$

Please apply these straw molecular models to daily classroom lessons.

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