Topic Exploration Pack

Activity Sheets

Theme: Organic Structures

Contents

Activity Sheet 1 – Answer Grid

Activity Sheet 3 – Easy Peasey Chineasy Building Blocks

火	日	木
FIRE	SUN	TREE
人	女	宀
PERSON	WOMAN	ROOF
月	口	山
MOON	MOUTH	MOUNTAIN

Activity Sheet 4 – Easy Peasey Chineasy Complex Words

Match the complex word symbol to the correct word.

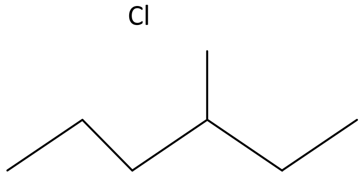
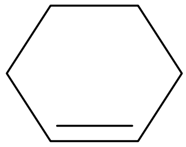
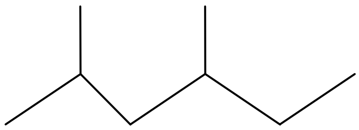
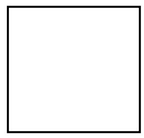
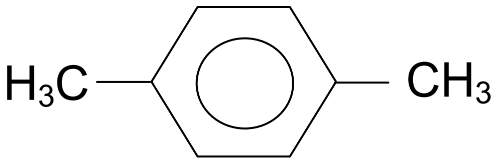
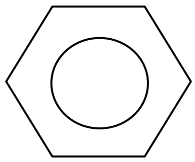
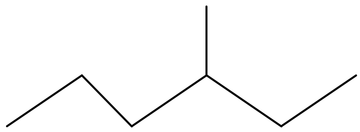
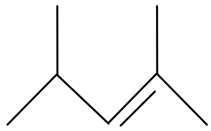
傘	啖
从	林
仙	森
晶	東
炎	來
焱	

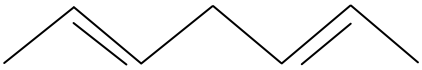
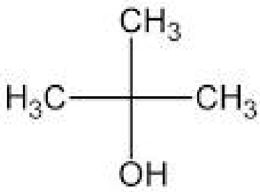
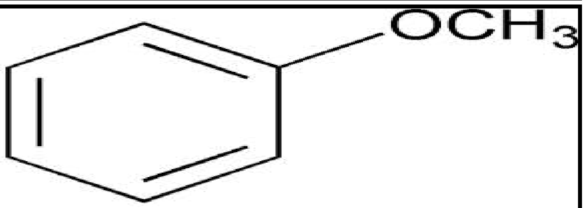
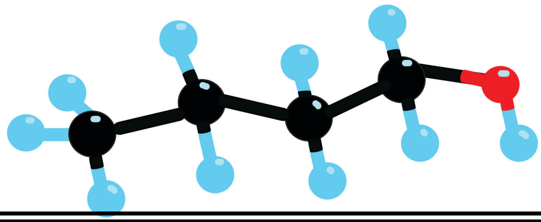
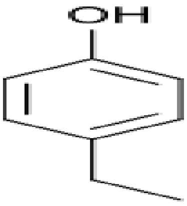
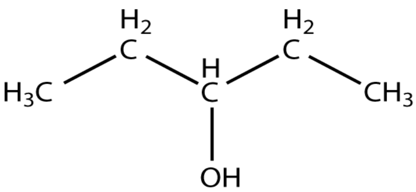
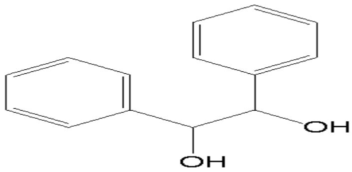
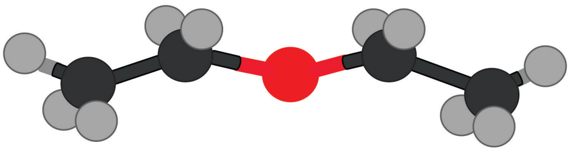
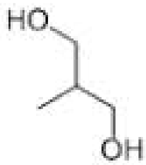
UMBRELLA	EAT
FOLLOW	WOOD
IMMORTAL	FOREST
SPARKLES	EAST
BURNING	TO COME
HOT FLAMES	

Answers

SYMBOL	WORD
傘	UMBRELLA (people in the tree)
从	FOLLOW (two people)
仙	IMMORTAL (people and mountain)
晶	SPARKLES (three suns)
炎	BURNING (two fires)
焱	HOT FLAMES (two people under fire)
啖	EAT (mouth and two fires)
林	WOOD (two trees)
森	FOREST (three trees)
東	EAST (tree with sun)
來	TO COME (Two people under a tree)

Activity Sheet 5 – Organic Structure Cards

1 	2 
3 	4 
5 	6 
7 CH_3 CH_3 | | $CH_3CHCH_2CHCH_3$	8 $CH_3C(CH_3)CHCH_3$
9 $CH_3CHCHCH_3$	10 
11 C_8H_{18}	12 

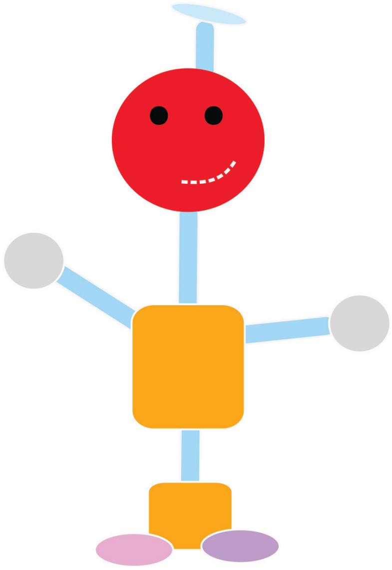
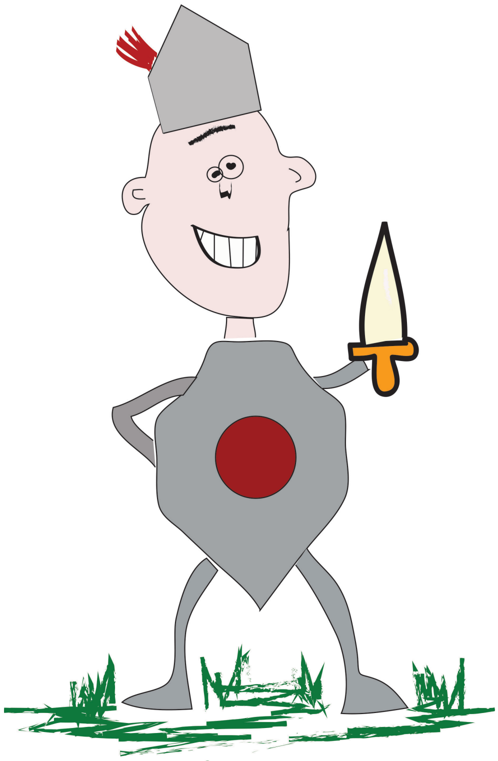
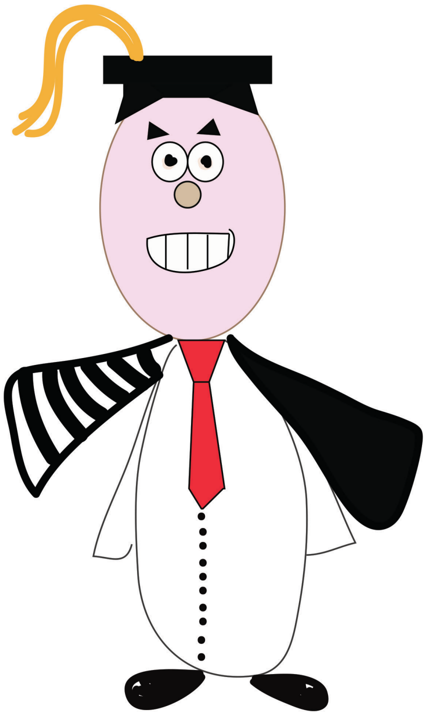
13 	14 
15 	16 
17 	18 
19 	20 
21 	22 
23 $CH_3CH(OH)CH_2CH_3$	24 $CH_2(OH)CH(OH)CH_2(OH)$

1 **3-Chlorohexane**	2 **Cyclohexene**
3 **2,4-dimethylhexane**	4 **Cyclobutane**
5 **1,4-dimethylbenzene**	6 **Benzene**
7 **2,4-dimethylpentane**	8 **2-methylbut-2-ene**
9 **but-2-ene**	10 **3 -methylhexane**
11 **Octane**	12 **2,4- dimethylpent-2-ene**
13 **2,5 heptadiene**	14 **2-methylpropan-2-ol**

15 **Methoxybenzene(anisole)**	16 **butan-1-ol**
17 **4-ethylphenol**	18 **3-ethoxypropane**
19 **pentan-3-ol**	20 **1,2-diphenyl-1,2 -ethandiol**
21 **Ethoxyethane (diethyl ether)**	22 **2-methyl-1,3-propandiol**
23 **Butan-2-ol**	24 **Propane 1,2,3 triol (Glycerol)**

Activity Sheet 6 – Organic Building Block Templates

Activity Sheet 7 – Meet the Experts

		
Molymodel Queen of Molecular Modelling	**Sir Structuris** Knight of the written structure (structural and displayed)	**Professor Paul Planar** 3D modelling expert
Demonstrate your molecular modelling skills.	Are you quick off the draw show the opposition your understanding of the written forms of this molecules structure.	Are you a dasher or can you wedge your way into this structure. Use your team mates to show you know how your molecule looks.

You will need :

9 Expert cards

3 Put Off Pick Cards

3 Perfect Pick Cards

Timer (eg egg timer)

Organic structure cards

Instructions:

Shuffle the 20 expert/pick cards and place face down on the table. (Each card is associated with a points award.)

Shuffle the structure

Game suitable for Teams of 3 (minimum 2 teams; maximum 4 teams)

Select an expert card for the round then select a structure or naming card.

Depending on the expert picked you will have to draw or model the molecule listed.

If a Put Off pick Card is chosen the team who have chosen can challenge an opposing team to complete the task in the expert of their choice. 5 points are awarded for a correct answer or deducted for an incorrect answer.

If a Perfect Pick Card is selected the team making the selection can choose which expert they wish to use and 5 points will be awarded for a correct answer.

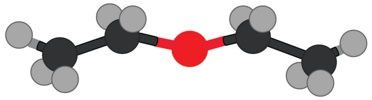
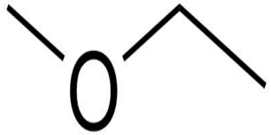
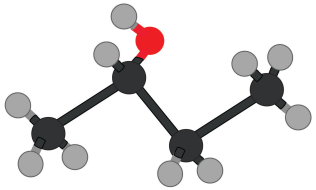
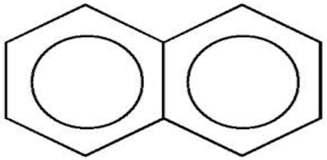
Each team should keep the expert cards they win and once all 20 expert cards have been selected the teams should add up their points to see who is the winner.

Insert pictures into points cards.

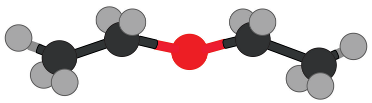
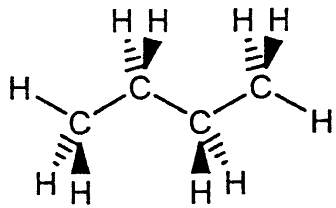
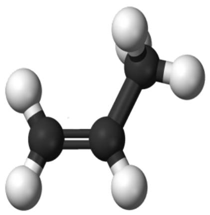
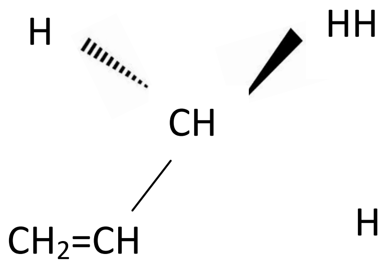
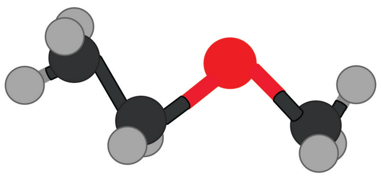
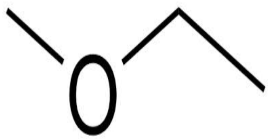
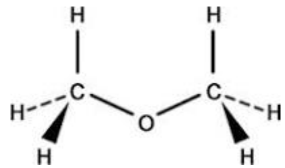
1	**1**	**1**	**Perfect Pick**	**Put Off pick**
2	**2**	**2**	**Perfect Pick**	**Put Off Pick**
3	**3**	**3**	**Perfect Pick**	**Put Off Pick**

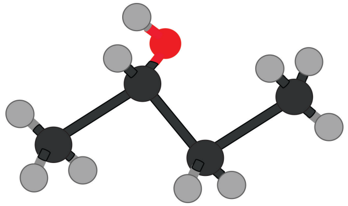
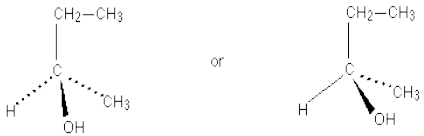
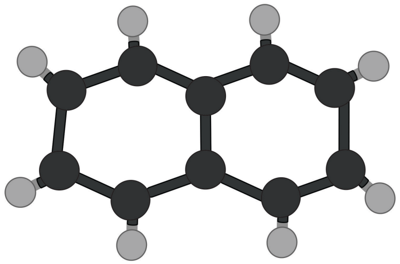
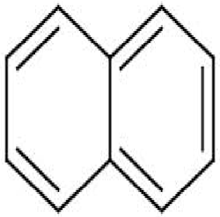
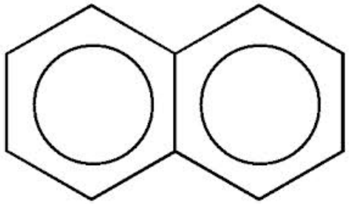
Methane	Ethane	Propane	Butane	Ethene
Ethene	Propene	But-1-ene	But-2-ene	Methoxy-methane
Methanol	Ethanol	Propan-1-ol	Propan-2-ol	Methoxy-ethane
Ethoxy-ethane	2-methyl propan-2-ol	Benzene	Methyl-benzene	Phenol
Methyl-propane	1,2,dichloro-ethene	cyclopropane	cyclobutane	Methylcyclo-propane

Activity Sheet 8 – Drawing Practice

MOLECULE	FULL DISPLAYED FORMULA	HOMOLOGOUS SERIES	MOLECULAR FORMULA	SKELETAL FORMULA	3D REPRESENTATION
			C_4H_{10}		
Prop-1-ene			C_3H_6		
					
Butan-2-ol					
Naphthalene			$C_{10}H_8$		

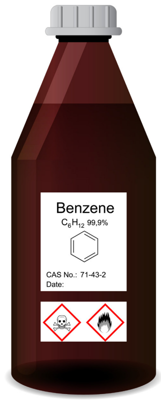
Activity Sheet 9 – Drawing Practice Answers

MOLECULE	FULL DISPLAYED FORMULA	HOMOLOGOUS SERIES	MOLECULAR FORMULA	SKELETAL FORMULA	3D REPRESENTATION
Butane		Alkane	CH_4		
Prop-1-ene		Alkene	C_3H_6		
Methoxyethane		Ether	C_2H_6O		

Butan-2-ol		Alcohol	C_4H_9OH		
Napthalene		arene	$C_{10}H_8$		

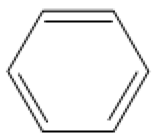
Activity Sheet 10 – The Arenes Answers

Arenes are a group of hydrocarbons based on a ring system and containing a system of electrons which are delocalised over the ring. The suffix –ene, refers to their un-saturation, as with the alkenes. Many of this homologous series have strong smells and so were defined as aromatic compounds (as opposed to aliphatic compounds which do not contain a ring system). However not all do and the ring system is now known not to be associated with the smell of the substance. Benzene was first isolated by Michael Faraday in 1825 as the result of experimentation with the by-products of burning whale and fish oil. He deduced that its' empirical formula was CH. As can be seen from the picture below (a sample of Faraday's benzene held by the Royal Institute), benzene is a colourless liquid, its molecular formula was later deduced to be C_6H_6. It is an important stock chemical for the chemical industry and began being manufactured on an industrial scale from coal tar in the mid 19th Century benzene. It had a wide range of uses from organic solvent to aftershaves. The substance is now known to be toxic and is now used mainly in industrial processes to create other substances.

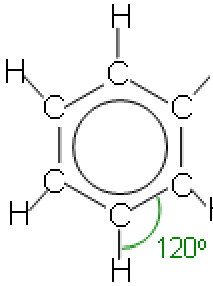


The molecular formula indicates that benzene must be extremely unsaturated, having an equal number of carbon atoms to hydrogen atoms however it is very unreactive and has its own characteristic properties, not behaving as other unsaturated molecules.

Whilst scientists knew the molecular formula of benzene was C_6H_6 the structure continued to puzzle them until 1865 when August Kekulé proposed a cyclic structure of alternate single and double bonds. Story has it that this structure came to him when he dreamt of a serpent eating its tail!



However it was not until 1925 using evidence from crystallography that Kathleen Lonsdale showed that there was uniform electron density over the whole molecule indicating the structure shown below. The benzene ring is a regular hexagonal, planar molecule, with equal bond angles of 120^{o}. The carbon-carbon bonds are of equal length, 0.139 nm, which lies between that of a carbon-carbon single bond (0.134nm) and a carbon-carbon double bond (0.154 nm.) All the hydrogens are indistinguishable from each other thus the uniform electron density is represented by a circle in the molecule although both structures are seen in text books.



The delocalisation of electrons around the ring result in far greater stability than it would have if Kekulé's proposed structure was correct. The types of reactions which Benzene will undergo will be those where the ring system is preserved. In order to disrupt the delocalised electron system will require more aggressive conditions, such as higher temperatures. The enthalpy change for the hydrogenation of benzene to form cyclohexane is -208 $KJmol^{-1}$. If we compare this to the reaction of cyclohexene with hydrogen an enthalpy change of -120 $KJmol^{-1}$ is shown. Assuming that the double bonds in Kekulé's benzene produce an enthalpy change 3 times that of an individual double bond we can see that the estimated enthalpy change is much higher than the measured one, indicating the stability of the structure.

There are a number of compounds derived from benzene. The rings can join together to form fused ring systems such as naphthalene or anthracene. In these structures the rings share a pair of carbon atoms when they join thus reducing the numbers of hydrogen atoms associated. Rather than drawing the structures with circles to represent the delocalised electron system; in these larger ring systems the bonds are represented by alternating double and single bonds. Benzene can also form an alkyl group with the loss of a hydrogen which is known as the phenyl group. The hydrogens within the structure can be replaced by a number of functional groups and therefore a range of aromatic compounds can be produced including halobenzene and phenol; a phenyl group with an associated hydroxyl group. Here the –OH group will behave very differently than in alcohols. Where two functional groups are attached to the benzene directly next to each other (eg 1,2) the molecule is given the prefix ortha-; if there is one atom between the groups (eg 1,3) the prefix becomes para- and if the groups are diametrically opposed (eg 1,4) the prefix is meta.

Questions:

What is the timeline for the development of our understanding of the structure of benzene?

Students should make reference to Faraday, Kekulé and Lonsdale.

What is the difference between aromatic and aliphatic compounds?

Aromatic compounds are often strong smelling and contain a ring system of delocalised electrons.

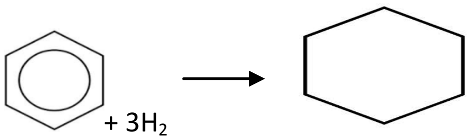
What evidence was there that Kekulé's proposed structure was incorrect?

- Structure of molecule - alternate bond lengths would give an irregular puckered structure where as benzene is a planar regular hexagon.
- Electron density – X-Ray crystallography indicates uniform density as opposed to specific areas of density associated with a double bond.
- Stability – thermodynamic experiments indicate that the enthalpy changes of various reactions are much higher than would be expected.

What is meant by hydrogenation?

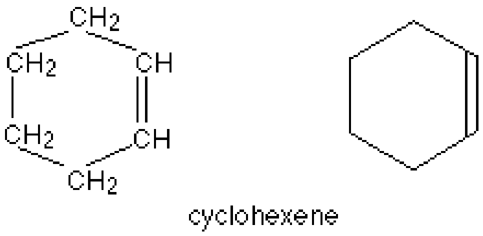
The addition of hydrogen to a molecule.

Write an equation of the hydrogenation of benzene referred to in the text. Use skeletal formula to represent the organic structures



What is the molecular formula for cyclohexene? Write out the full structural formula and draw the displayed formula and skeletal formula for this molecule.

C_6H_{10}



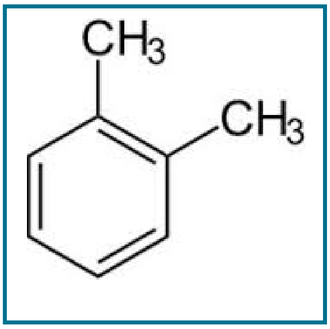
Why is benzene used only for industrial processes?

Due to its toxicity benzene is no longer safe for domestic commercial use.

Based on information in the text what is the enthalpy change associated with Kekulé's Benzene structure.

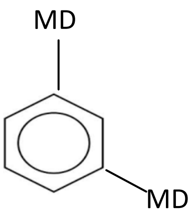
3 x (-120 $KJmol^{-1}$) = - 360 $KJmol^{-1}$

Benzene reacts to produce 1,2-dimethylbenzene. Draw the skeletal structure of this molecule.



And finally! Can you solve the puzzle? Can you come up with your own!

Kekulé's proposed structure for Benzene proved to be a

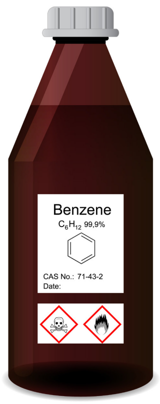


(paradox – based on the positioning of the MD's (representing docs or doctors!)

Adapted from Otter, C. and Stephenson, K. (2008) *Arenes* p277-p279, Heinneman and http://www.rigb.org/our-history/iconic-objects/iconic-objects-list/faraday-benzene.

Activity Sheet 11 – The Arenes

Arenes are a group of hydrocarbons based on a ring system and containing a system of electrons which are delocalised over the ring. The suffix –ene, refers to their un-saturation, as with the alkenes. Many of this homologous series have strong smells and so were defined as aromatic compounds (as opposed to aliphatic compounds which do not contain a ring system). However not all do and the ring system is now known not to be associated with the smell of the substance. Benzene was first isolated by Michael Faraday in 1825 as the result of experimentation with the by-products of burning whale and fish oil. He deduced that its' empirical formula was CH. As can be seen from the picture below (a sample of Faraday's benzene held by the Royal Institute), benzene is a colourless liquid, its molecular formula was later deduced to be C_6H_6. It is an important stock chemical for the chemical industry and began being manufactured on an industrial scale from coal tar in the mid 19th Century benzene. It had a wide range of uses from organic solvent to aftershaves. The substance is now known to be toxic and is now used mainly in industrial processes to create other substances.



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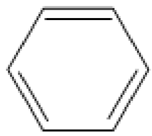
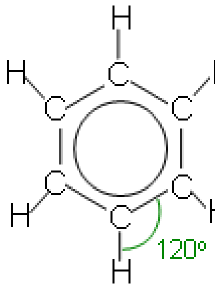


However it was not until 1925 using evidence from crystallography that Kathleen Lonsdale showed that there was uniform electron density over the whole molecule indicating the structure shown below. The benzene ring is a regular hexagonal, planar molecule, with equal bond angles of 120^{o}. The carbon-carbon bonds are of equal length, 0.139 nm, which lies between that of a carbon-carbon single bond (0.134nm) and a carbon-carbon double bond (0.154 nm.) All the hydrogens are indistinguishable from each other thus the uniform electron density is represented by a circle in the molecule although both structures are seen in text books.



The delocalisation of electrons around the ring result in far greater stability than it would have if Kekulé's proposed structure was correct. The types of reactions which Benzene will undergo will be those where the ring system is preserved. In order to disrupt the delocalised electron system will require more aggressive conditions, such as higher temperatures. The enthalpy change for the hydrogenation of benzene to form cyclohexane is -208 $KJmol^{-1}$. If we compare this to the reaction of cyclohexene with hydrogen an enthalpy change of -120 $KJmol^{-1}$ is shown. Assuming that the double bonds in Kekulé's benzene produce an enthalpy change 3 times that of an individual double bond we can see that the estimated enthalpy change is much higher than the measured one, indicating the stability of the structure.

There are a number of compounds derived from benzene. The rings can join together to form fused ring systems such as naphthalene or anthracene. In these structures the rings share a pair of carbon atoms when they join thus reducing the numbers of hydrogen atoms associated. Rather than drawing the structures with circles to represent the delocalised electron system; in these larger ring systems the bonds are represented by alternating double and single bonds. Benzene can also form an alkyl group with the loss of a hydrogen which is known as the phenyl group. The hydrogens within the structure can be replaced by a number of functional groups and therefore a range of aromatic compounds can be produced including halobenzene and phenol; a phenyl group with an associated hydroxyl group. Here the –OH group will behave very differently than in alcohols. Where two functional groups are attached to the benzene directly next to each other (eg 1,2) the molecule is given the prefix ortha-; if there is one atom between the groups (eg 1,3) the prefix becomes para- and if the groups are diametrically opposed (eg 1,4) the prefix is meta.

Questions:

What is the timeline for the development of our understanding of the structure of benzene?

What is the difference between aromatic and aliphatic compounds?

What evidence was there that Kekulé's proposed structure was incorrect?

What is meant by hydrogenation?

Write an equation of the hydrogenation of benzene referred to in the text. Use skeletal formula to represent the organic structures

What is the molecular formula for cyclohexene? Write out the full structural formula and draw the displayed formula and skeletal formula for this molecule.

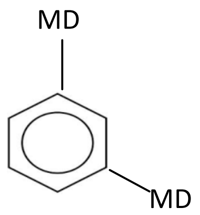
Why is benzene used only for industrial processes?

Based on information in the text what is the enthalpy change associated with Kekulé's Benzene structure.

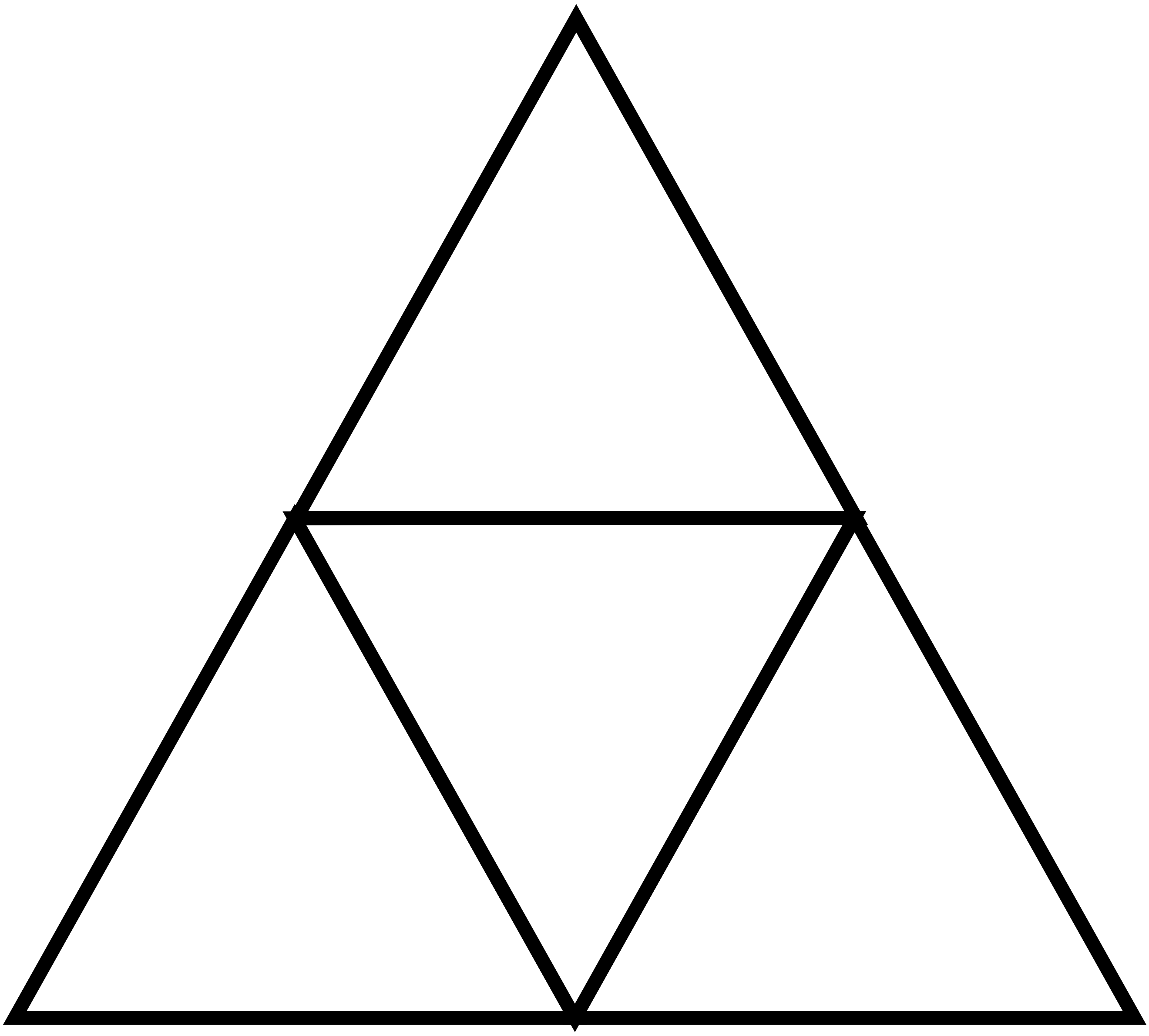
Benzene reacts to produce 1,2-dimethylbenzene. Draw the skeletal structure of this molecule.

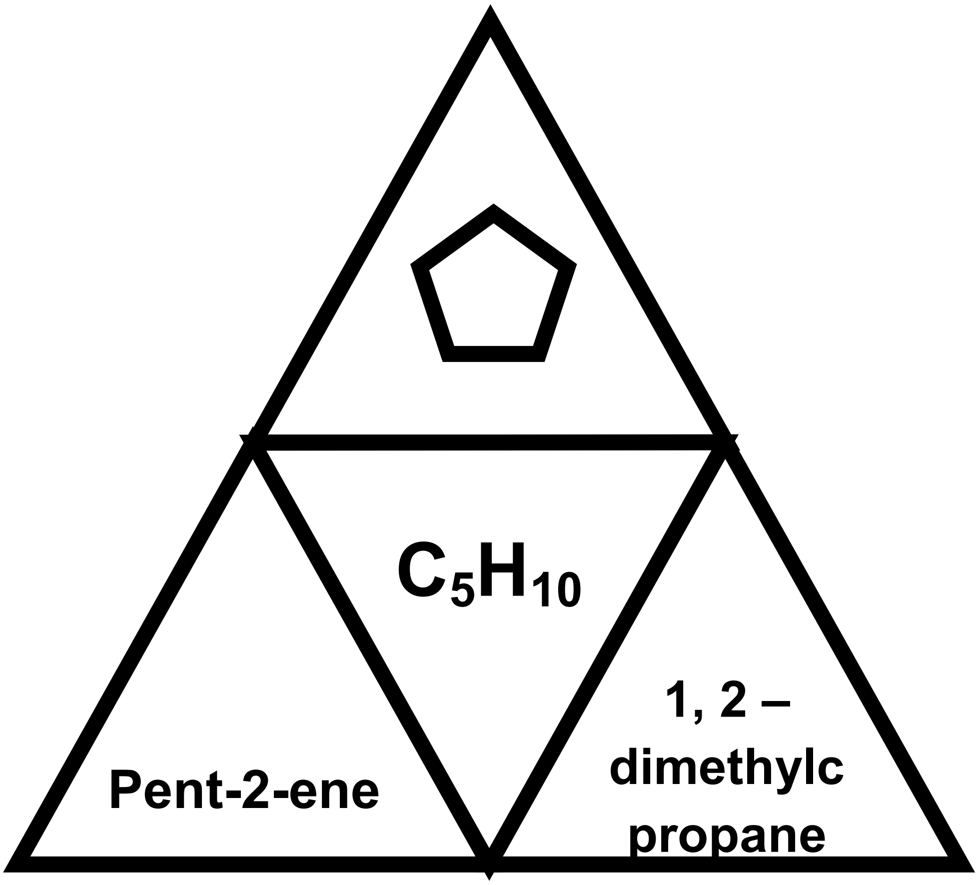
And finally! Can you solve the puzzle? Can you come up with your own!

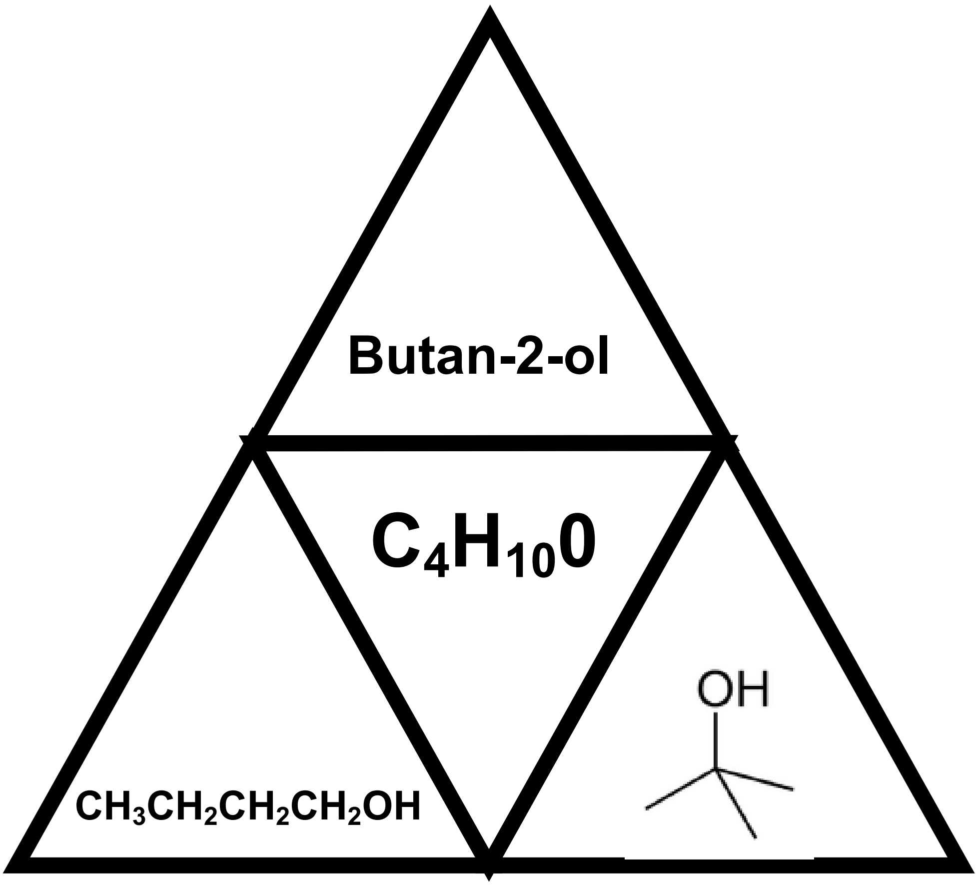
Kekulé's proposed structure for Benzene proved to be a



Activity Sheet 12 – Isomeronimoes

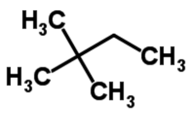



C_5H_{10}
Pent-2-ene
1, 2 –
dimethylc
propane


Butan-2-ol
$C_4H_{10}0$
$CH_3CH_2CH_2CH_2OH$
OH

Hexane

C_6H_{14}



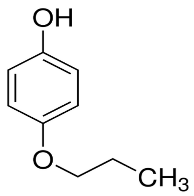
CH3CH2CH(CH3)

CH2CH3

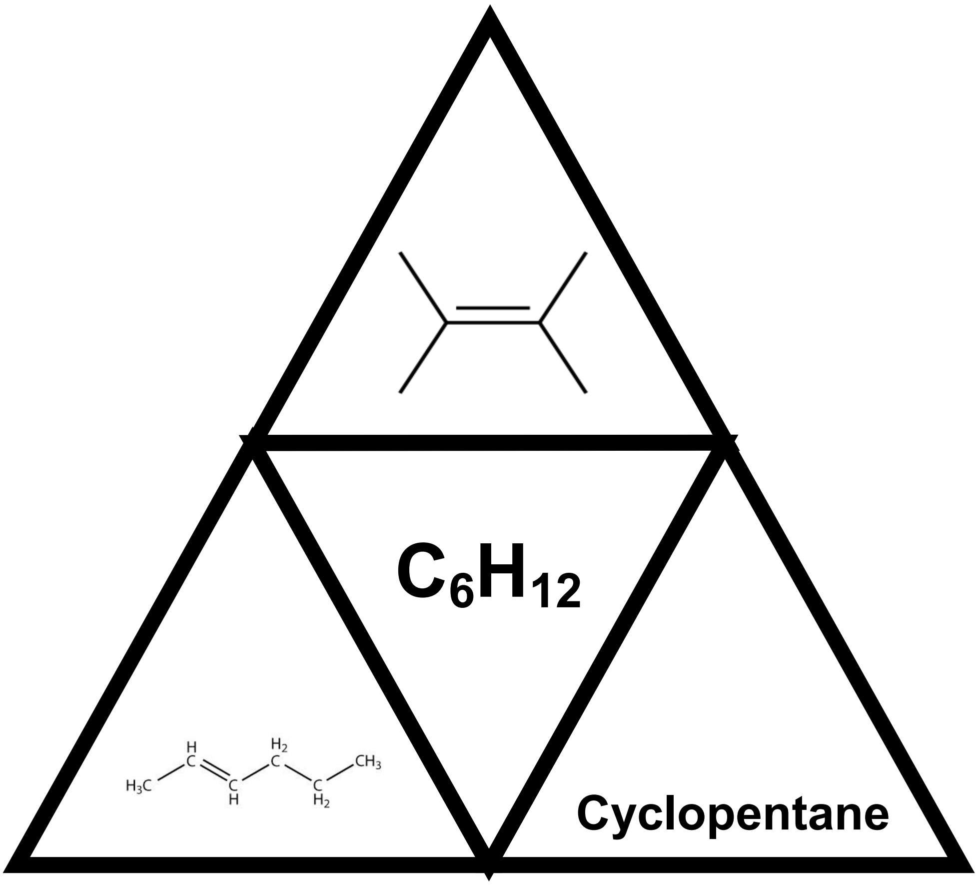
Dimethoxymethyl

benzene

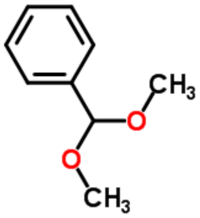
$C_9H_{12}0_2$



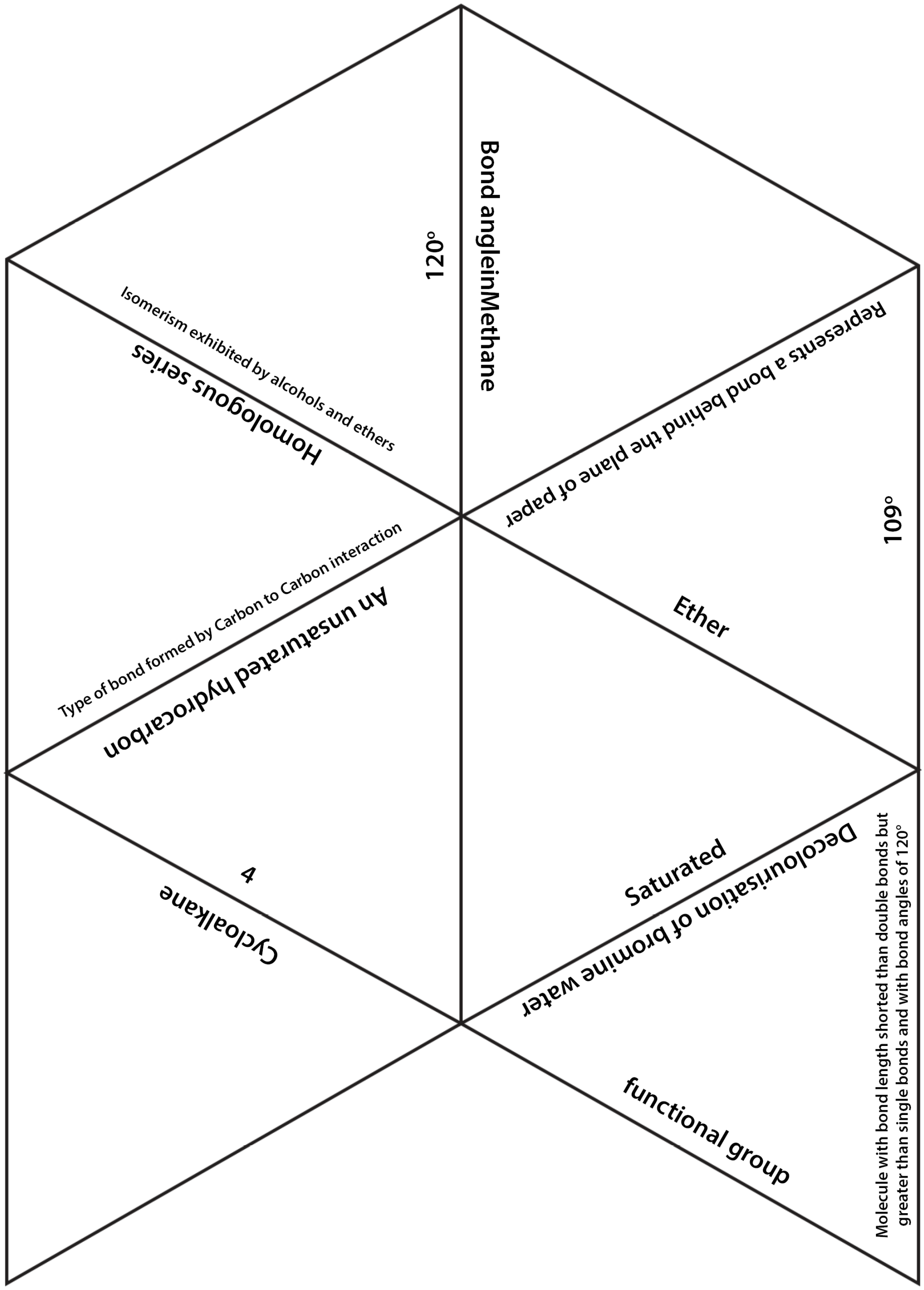
$C_6H_5CH_2OCH_2CH_2OH$

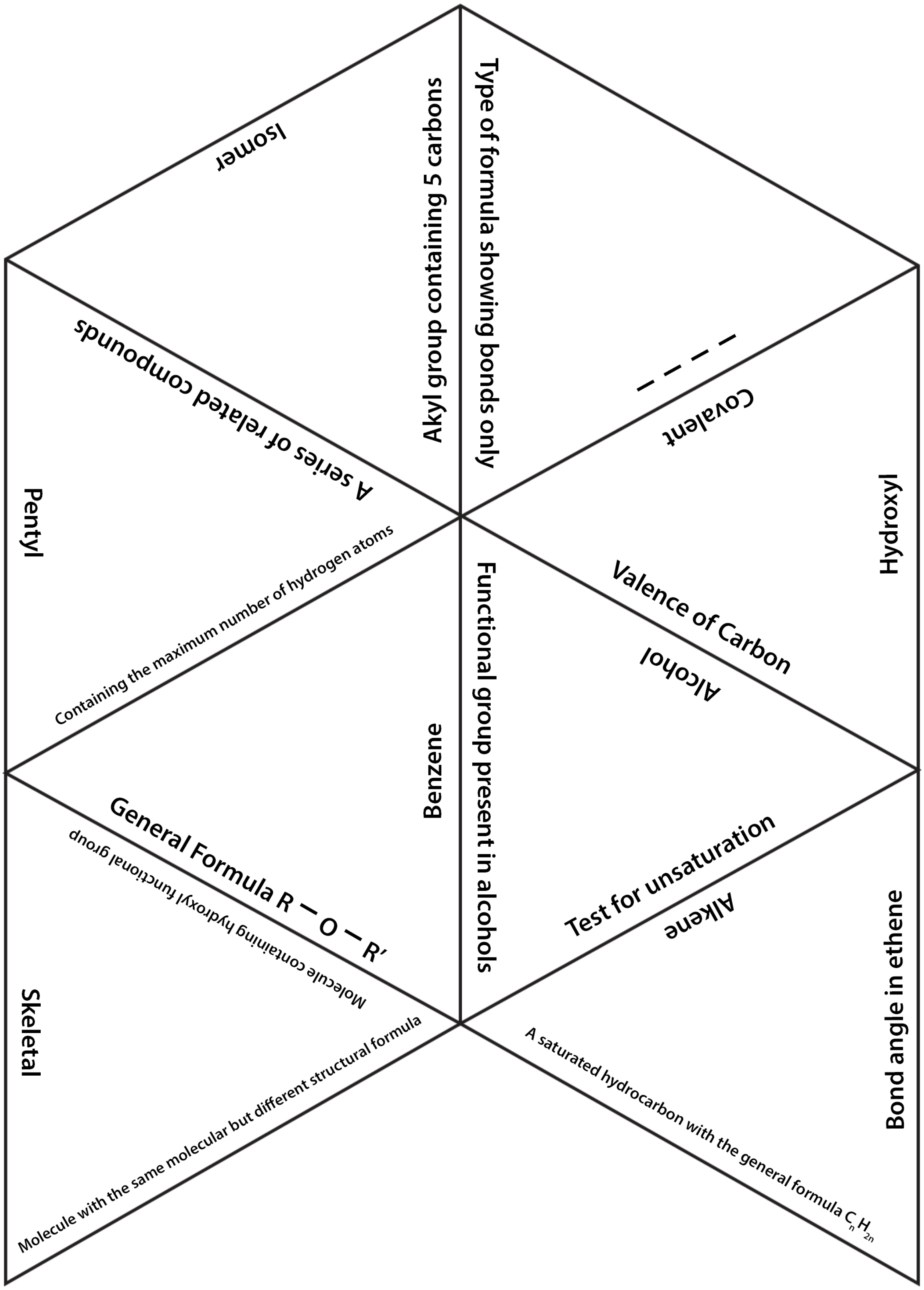

C_6H_{12}
Cyclopentane

Activity Sheet 13 – Isomeronimoes Answers

C_5H_{10}	Pent-2-ene	Cyclopentane	1,2 dimethylcyclo propane
C_4H_{10}	Butan-2-ol	Butan-1-ol	2 methylpropan-2-ol
C_6H_{14}	Hexane	2,2-dimethyl butane	3 methylpentane
$C_9H_{12}O_2$		4-(2-Methoxyethyl) phenol	Benzyloxy ethanol
C_6H_{12}	1,2-dimethyl butane	Hex-2-ene	cyclohexane

Activity Sheet 15 – Tarsia




Isomer
Akyl group containing 5 carbons
Type of formula showing bonds only
Covalent
– – – –
A series of related compounds
Pentyl
Hydroxyl
Containing the maximum number of hydrogen atoms
Functional group present in alcohols
Valence of Carbon
Alcohol
Benzene
General Formula R – O – R′
Molecule containing hydroxyl functional group
Test for unsaturation
Alkene
Skeletal
Bond angle in ethene
Molecule with the same molecular but different structural formula
A saturated hydrocarbon with the general formula C_nH_{2n}

Activity Sheet 16 – Answer for activity 15