Bonding workshop

Covalent bonding and hydrocarbons

Contents

Learning objectives

By the end of this session, you will be able to:

- Explain how a covalent bond is formed between two atoms.
- Construct models for at least three hydrocarbons.
- Draw the displayed structures for three alkanes and three alkenes.
- Work out the structures for at least two additional functional groups and draw their displayed formulas.

Acknowledgements

This resource was originally developed by Liverpool John Moores University to support outreach work delivered as part of the Chemistry for All Project.

To find out more about the project, and get more resources to help widen participation, visit our Outreach resources hub: rsc.li/3CJX7M3.

Activity 1: hydrocarbons

Draw lines to match the terms in the first column with their definition.

Elements	*	*	a substance formed when two or more different chemical elements are chemically bonded together
Compound	*	*	a hydrocarbon containing only single bonds between the carbon atoms
Hydrocarbon	*	*	the simplest substances that cannot be broken down using chemical methods
Saturated hydrocarbon	*	*	a compound containing hydrogen and carbon atoms only
Unsaturated hydrocarbon	*	*	a hydrocarbon containing one or more double or triple bonds between the carbon atoms

Career link

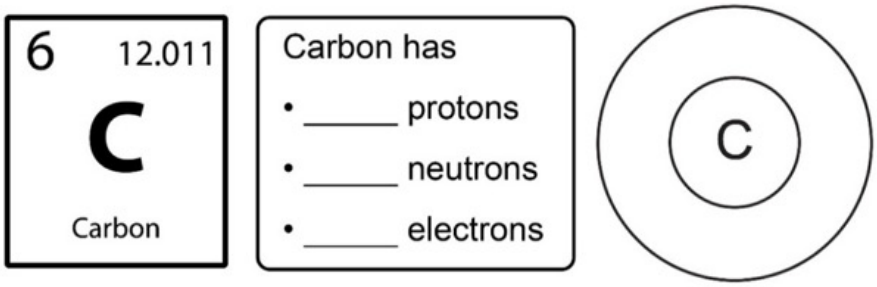
Science communicator

Watch the video on **slide 6** of the PowerPoint, also available from rsc.li/3CAOzIi, which introduces a science communicator. Fernando uses his scientific knowledge to uncover and translate complicated science for the public.

Activity 2: structure of hydrocarbons

1. Fill in the number of subatomic particles for carbon and hydrogen. Complete the diagrams below to show the structure of each atom, using an X for the electrons.

(a) Carbon



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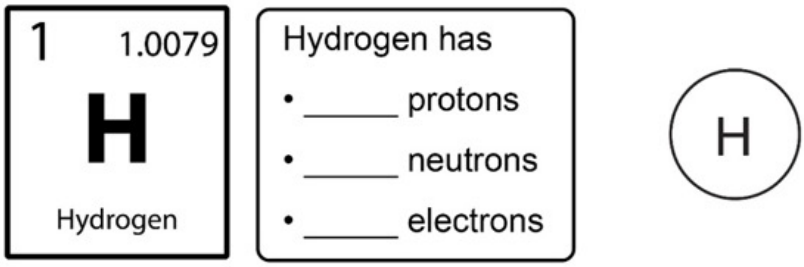
(b) Hydrogen



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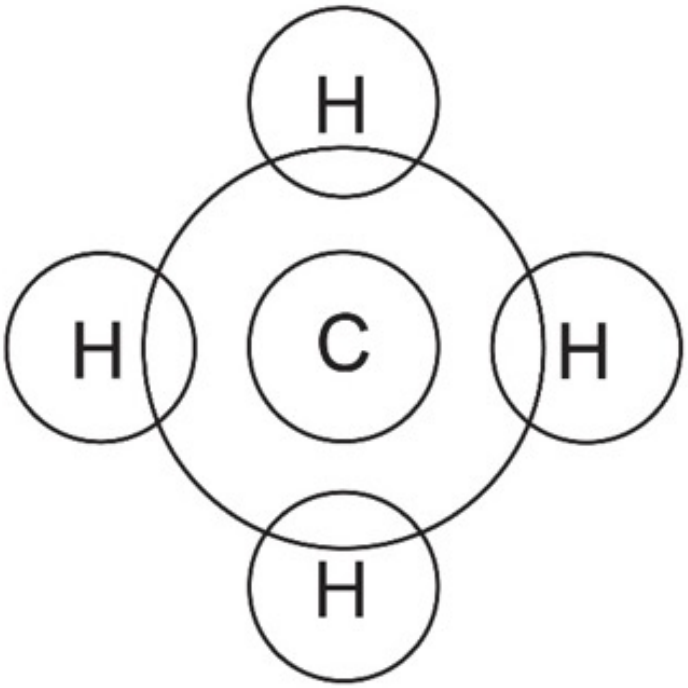
Carbon and other non-metallic atoms bond by sharing electrons.

This is known as covalent bonding. Electrons are shared between bonding atoms, so that all atoms gain the stability of a full outer shell.

2. Complete the dot and cross diagram to show the bonding that occurs between carbon and hydrogen in methane. Use dots to show the electrons in carbon and crosses to show the electrons in hydrogen.



Activity 3: simple molecules

In molymod kits each ball represents an atom and each stick represents a bonding pair of electrons.

Molymod atoms

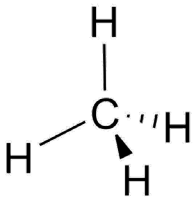
Colour of ball	Atom name	Chemical symbol	Number of bonds
	hydrogen	H	1
	carbon	C	4
	oxygen	O	2
	nitrogen	N	3
	sulfur	S	2
	chlorine	Cl	1
	iodine	I	1
	aluminium	Al	4

1. As part of a group, build models of the following simple molecules. Complete the table below. The first row has been filled in for you.

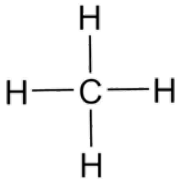
Molecule	Molecular formula	Molymod model built? X/✓	Displayed formula
Example: hydrogen	H_2	✓	H—H
chlorine	Cl_2		
hydrogen chloride	HCl		
water	H_2O		
ammonia	NH_3		
oxygen	O_2		
carbon dioxide	CO_2		

Activity 4: alkanes

The simplest form of hydrocarbon is an alkane. Alkanes are saturated hydrocarbons, which means that they contain only single bonds between two carbon atoms. Each carbon atom makes four bonds by joining to other carbon atoms or hydrogen atoms. Hydrogen atoms form one bond each.



1. Build models of the following alkanes. Complete the table below by drawing their displayed formulas. The first displayed formula has been drawn for you.

Molecule	Molecular formula	Molymod model built? X/✓	Displayed formula
methane	CH_4		
ethane	C_2H_6		
propane	C_3H_8		
butane	C_4H_{10}		

2. Describe how the number of hydrogen atoms changes as the number of carbon atoms in the chain increases.

_____

_____

3. The general formula for alkanes is:

_____

4. Use the general formula for alkanes to predict the formula of the following molecules. Build them using the molymod kits to check your predictions.

Molecule	Molecular formula	Molymod model built? X/✓	Displayed formula
pentane five carbon atoms			
hexane six carbon atoms			
heptane seven carbon atoms			
octane eight carbon atoms			

Challenge: trends and patterns in alkanes

5. Use the data provided in the table to answer the following questions.

Name	Formula	Melting point (°C)	Boiling point (°C)
methane	CH_4	−182	−161
ethane	CH_3CH_3	−183	−88
propane	$CH_3CH_2CH_3$	−188	−42
butane	$CH_3(CH_2)_2CH_3$	−138	0
pentane	$CH_3(CH_2)_3CH_3$	−130	36
hexane	$CH_3(CH_2)_4CH_3$	−95	69
heptane	$CH_3(CH_2)_5CH_3$	−90	99
octane	$CH_3(CH_2)_6CH_3$	−57	126
nonane	$CH_3(CH_2)_7CH_3$	−53	151
decane	$CH_3(CH_2)_8CH_3$	−29	174

(a) Which alkane has the lowest boiling point?

(b) Name three alkanes which are liquids at room temperature.

(c) What do you notice about the trends in boiling point and melting point?

(d) Explain this trend using the term **intermolecular forces**.

Career link

Project leader of enhanced experimentation

Stuart's video job profile, available on **slide 22** and from rsc.li/3GQvi87, shows his role as a project leader of enhanced experimentation in oil and gas at Shell. He uses robots, computer modelling and data to research and develop new ways to use crude oil and gas.

Activity 5: reactions of alkanes

Fuels react with oxygen to release energy. Complete combustion happens in a plentiful supply of oxygen. Incomplete combustion occurs when the supply of oxygen is limited.

In general, for **complete combustion**:

alkane + oxygen → carbon dioxide + water

For example,

methane + oxygen → carbon dioxide + water

$$CH_4\,(g) + 2O_2\,(g) \rightarrow CO_2\,(g) + 2H_2O\,(g)$$

In general, for **incomplete combustion**:

alkane + oxygen → carbon monoxide + carbon + water

For example,

methane + oxygen → carbon monoxide + carbon + water

$$3CH_4\,(g) + 4O_2\,(g) \rightarrow 2CO\,(g) + C\,(s) + 6H_2O\,(g)$$

Demonstration of a Bunsen burner flame

The gas used in Bunsen burners is methane. Watch the demonstration and observe what happens when the air hole of a Bunsen burner is opened and closed.

1. Delete words on the diagrams below to describe what happened.

(a) Air hole *open/closed*

Complete/incomplete combustion

(b) Air hole *open/closed*

Complete/incomplete combustion

Demonstration of a controlled explosion of methane

2. Describe your observations.

3. Explain what happened.

Demonstration of methane bubbles

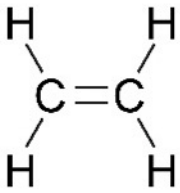
4. Describe what happened in the demonstration.

5. Why did the methane bubbles float up to the ceiling?

Activity 6: alkenes

Another family of organic compounds are the **alkenes**. They are also hydrocarbons as they only contain hydrogen and carbon atoms. However, they are **unsaturated** compounds, which means that they contain at least one **double bond** between two carbon atoms.

1. (a) Label the double bond in this displayed formula of an alkene.



(b) Using your molymod kit, build each of the alkenes named in the table below and draw their displayed formulas.

Molecule	Molecular formula	Molymod model built? X/✓	Displayed formula
ethene	C_2H_4		
propene	C_3H_6		
butene	C_4H_8		

2. Why does a molecule called methene not exist?

3. Describe how the number of hydrogen atoms changes as the number of carbon atoms in the chain increases.

4. The general formula for alkenes is:

Career link

School science technician

Watch Sandrine's job profile, available on **slide 48** and from rsc.li/3ZpDhAv. She is a school science technician and uses her knowledge and skills to design, prepare and test practicals for chemistry lessons and extracurricular activities.

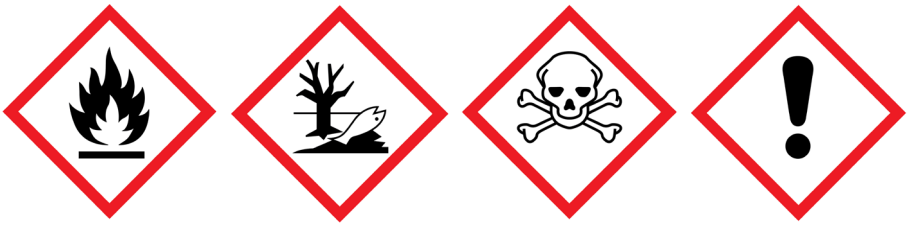
5. Use the general formula for alkenes to predict the formula of each of the alkenes in the table below. Build each using the molymod kit to see if you are correct.

Molecule	Molecular formula	Molymod model built? X/✓	Displayed formula
pentene five carbon atoms			
hexene six carbon atoms			
heptene seven carbon atoms			
octene eight carbon atoms			

6. Does it matter where the double bond is in the molecule? Why?

Activity 7: reactions of alkenes

The double bond of the alkene allows us to distinguish them from alkanes because they undergo an addition reaction with a halogen.



Safety and hazards

Wear safety glasses

To do:

1. You have two test tubes which contain bromine water, Br_2 (aq).

   (a) Remove the bung of the first test tube. Quickly add one drop of an alkane (hexane) and replace the bung immediately. Take care not to spill the test tube as bromine water and hexane are hazardous.

   (b) Agitate the test tube by waggling it gently between your fingers.

   (c) Note your observations in the table below.

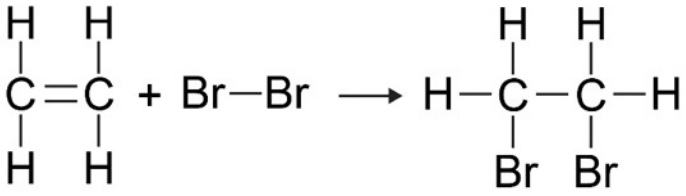
   (d) Repeat steps (a) to (c) with an alkene (hexene) using the second tube of bromine water.

Alkane or alkene	Appearance of bromine water (Br_2 (aq)) before adding the alkane/alkene	Appearance of bromine water (Br_2 (aq)) after adding the alkane/alkene
hexane		
hexene		

To answer:

Look at the reaction of bromine water and ethene.

ethene + bromine ⟶ 1,2-dibromoethane



2. Use this reaction to explain your observations.

Activity 8: functional groups

1. Build the following organic molecules using your molymod kit and try to identify the functional group (what makes it different from an alkane?).

Functional group	Example compound name and formula	Molymod model built? X/✓	Displayed formula
alkene	butene C_4H_8		
alcohol	ethanol CH_3CH_2OH		
carboxylic acid	ethanoic acid CH_3COOH		
aldehyde	propanal CH_3CH_2CHO		
ketone	propanone CH_3COCH_3		

2. Circle the functional group in each displayed formula you have drawn.

Homework activity

Fill in the gaps

1. Combustion takes place when a fuel burns in oxygen.

When there is a plentiful supply of oxygen, _____ combustion takes place.

The general equation for this reaction is:

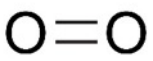
fuel + oxygen → _____ + water

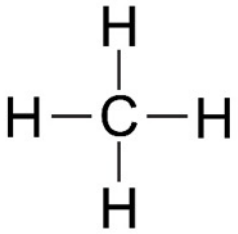
When the oxygen supply is limited, _____ combustion takes place.

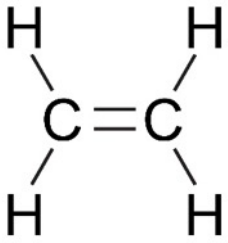
The general equation for this reaction is:

fuel + oxygen → carbon monoxide + _____ + water

2. Can you give the name and molecular formula for each of the molecules below?







Name: _____ Name: _____ Name: _____

Formula: _____ Formula: _____ Formula: _____