CHEMDU · COMMUNITY CHEMISTRY · LEVEL 2 ADVANCED

LECTURE L2-13

Organic Chemistry

The Carbon That Built You: Why There Are Millions of Organic Molecules

Duration: 75 minutes

Advanced lecture script — pre-requisite: Level 1

HOOK (3 minutes)

Teacher holds up (or shows photos of):

A plastic water bottle (PET)

A bottle of olive oil

A piece of fruit

A bottle of vanilla extract

Teacher says: "The plastic bottle in your hand. The oil in your pan. The sugar in your fruit. The vanilla in your cookies. What do they all have in common?

They're all made of carbon — the most versatile element on Earth.

There are millions of organic molecules. Most of the chemicals you interact with every day are organic.

- Today's question: What makes carbon so special — and how do you name and draw organic molecules? *

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

Explain why carbon can form millions of different molecules

Draw and name simple alkanes (methane, ethane, propane, butane)

Identify common functional groups (alcohols, carboxylic acids, esters)

Recognize organic molecules in household products by name"

SEGMENT 1: Why Carbon Is Special (8 minutes)

Teacher says: "Before we dive into organic chemistry, let's understand why carbon is the star of the show."

Carbon's Unique Properties

Property	What It Means	Why It Matters
4 valence electrons	Carbon can form 4 covalent bonds	Can bond to up to 4 other atoms
Small atomic size	Bonds are strong and stable	Molecules don't fall apart easily
Bonds to itself (catenation)	Carbon atoms can chain together	Forms long chains, branches, and rings
Bonds to other elements	Carbon bonds with H, O, N, halogens, etc.	Creates millions of different functional groups

Teacher: "No other element can form such a vast number of stable compounds. Silicon (under carbon on the periodic table) can form chains too, but they're much less stable.

That's why life is carbon-based, not silicon-based."

Carbon Bonding Review (from L2-3)

Bond Type	Example	Found In
Single bond (C-C)	Ethane (C_2H_6)	Saturated fats, plastics
Double bond (C=C)	Ethene (C_2H_4)	Unsaturated fats (olive oil), fruits (ripening)
Triple bond (C≡C)	Ethyne (C_2H_2 — acetylene)	Welding torches

Quick check (show of hands / chat): "How many bonds can carbon form?" (4) "What does catenation mean?" (Carbon atoms bonding to each other in chains)

Teacher: "Good. Now let's learn how to name and draw the simplest organic molecules — the alkanes."

SEGMENT 2: Alkanes — The Simplest Hydrocarbons (12 minutes)

Teacher says: "Hydrocarbons are molecules made only of carbon and hydrogen. Alkanes are hydrocarbons with only single bonds."

Alkane: A hydrocarbon with only single bonds (saturated — no room for more hydrogen).

Naming Alkanes — Prefixes You Must Know

Number of Carbons	Prefix	Formula	Household Example
1	Meth-	CH_4	Natural gas (methane)
2	Eth-	C_2H_6	Lighter fuel (ethane)
3	Prop-	C_3H_8	Propane (grill tanks)
4	But-	C_4H_{10}	Butane (lighters, camp stoves)
5	Pent-	C_5H_{12}	Pentane (blowing agent for foam)
6	Hex-	C_6H_{14}	Hexane (solvent in glues)
7	Hept-	C_7H_{16}	Heptane (gasoline component)

Number of Carbons	Prefix	Formula	Household Example
8	Oct-	C_8H_{18}	Octane (gasoline rating)
9	Non-	C_9H_{20}	Nonane (kerosene component)
10	Dec-	$C_{10}H_{22}$	Decane (jet fuel component)

Teacher: *"The general formula for alkanes is C_nH_{2n+2}. For methane (n=1): CH_4. For ethane (n=2): C_2H_6."*

Drawing Alkanes — Line-Angle Structures

Teacher: "Chemists don't draw all the C-H bonds. Instead, they use line-angle structures (skeletal formulas)."

Rule	Example
Each vertex (corner) is a carbon atom	A hexagon = 6 carbons
Hydrogen atoms are implied (not drawn)	Each carbon has enough H to make 4 bonds
Lines represent bonds	Single line = single bond; double line = double bond

Draw these on the board or screen:

text

Methane (CH_4): C (or just the letter C — too small for line-angle)

Ethane (C_2H_6): — (a single line between two carbons)

Propane (C_3H_8): ——— (a zigzag of three carbons)

Butane (C_4H_{10}): ———— (a zigzag of four carbons)

Teacher: "For longer chains, you draw a zigzag line. Each corner is a carbon atom."

Isomers — Same Formula, Different Structure

Isomers (EYE-soh-mers) are molecules with the same molecular formula but different arrangements of atoms.

Example: Butane (C_4H_{10})

Isomer	Structure	Boiling Point	Use
n-butane (normal butane)	Straight chain	-0.5°C	Lighters, camping fuel

Isomer	Structure	Boiling Point	Use
isobutane (2-methylpropane)	Branched chain	-11.7°C	Refrigerant (replaces Freon)

Teacher: "Both are C_4H_{10}, but they have different properties because of their different shapes. That's isomerism — and it's everywhere in organic chemistry."

Partner talk (1 minute): "Tell your partner: What is the alkane with 3 carbons called? (Propane). With 8 carbons? (Octane)."

SEGMENT 3: Functional Groups — The Reactive Parts (15 minutes)

Teacher says: "Alkanes are relatively unreactive. Functional groups are specific atoms or bonds that make molecules reactive and determine their chemical behavior."

Functional group: A specific arrangement of atoms that gives a molecule its characteristic properties.

Common Functional Groups — With Household Examples

Functional Group	Structure	Example	Household Product
Alcohol	-OH (hydroxyl)	Ethanol (CH_3CH_2OH)	Rubbing alcohol, vodka, hand sanitizer
Carboxylic acid	-COOH (carboxyl)	Acetic acid (CH_3COOH)	Vinegar
Ester	-COO-	Ethyl acetate	Nail polish remover, fruit flavors
Aldehyde	-CHO	Vanillin	Vanilla extract
Ketone	-CO- (carbonyl in middle)	Acetone (CH_3COCH_3)	Nail polish remover
Amine	$-NH_2$	Ethylamine	Amino acids, proteins
Ether	-O- (oxygen between carbons)	Diethyl ether	Starting fluid, formerly an anesthetic

Household Example 1: Alcohols

Alcohol	Formula	Where You Find It	Boiling Point
Methanol	CH_3OH	Windshield washer fluid, racing fuel	65°C (toxic — do not drink)

Alcohol	Formula	Where You Find It	Boiling Point
Ethanol	CH_3CH_2OH	Alcoholic beverages, hand sanitizer, gasoline additive	78°C
Isopropanol	$(CH_3)_2CHOH$	Rubbing alcohol, disinfectant wipes	82°C

Teacher: "All alcohols have an -OH group. That's why they mix with water (the O-H bond can hydrogen bond). But as the carbon chain gets longer, alcohols become less water-soluble."

Household Example 2: Carboxylic Acids

Acid	Formula	Where You Find It	pH
Acetic acid	CH_3COOH	Vinegar (5% solution)	~2.5
Citric acid	$C_6H_8O_7$	Lemons, limes, soda	~2.2
Lactic acid	$C_3H_6O_3$	Sour milk, yogurt, muscles after exercise	~3.0
Butyric acid	$C_4H_8O_2$	Rancid butter, vomit (smells terrible!)	~4.0

Teacher: "The -COOH group is what makes these acids sour and reactive with bases (like baking soda)."

Household Example 3: Esters — The Smell of Fruit

Teacher: "Esters are responsible for most fruit smells and flavors. They form when a carboxylic acid reacts with an alcohol."

Ester	Smell/Taste	Found In
Ethyl acetate	Fruity (pear)	Nail polish remover, fruit ripening
Isoamyl acetate	Banana	Bananas, candy flavoring
Methyl butyrate	Apple	Apples, pineapple
Octyl acetate	Orange	Oranges
Ethyl butyrate	Pineapple	Pineapples

Teacher: "Next time you eat a fruit-flavored candy, check the ingredients — you'll probably see an ester listed as 'natural flavor' or 'artificial flavor'."

Partner talk (1 minute): "Tell your partner: What functional group is in vinegar? (Carboxylic acid — -COOH). What functional group is in rubbing alcohol? (Alcohol — -OH)."

SEGMENT 4: Drawing and Naming Simple Organic Molecules (10 minutes)

Teacher says: "Now let's practice drawing and naming organic molecules using IUPAC nomenclature (the official naming system)."

IUPAC Naming Rules (Simplified)

Step	What to Do	Example
1	Find the longest continuous carbon chain	4 carbons = butane
2	Identify any functional groups	-OH = alcohol
3	Number the chain to give the functional group the lowest number	Alcohol on carbon 2
4	Name: [number]-[substituent] [parent alkane]	2-butanol

Worked Example 1: Ethanol

Step	Analysis
Longest carbon chain	2 carbons → eth-
Functional group	-OH (alcohol) → suffix -ol
Name	Ethanol (CH_3CH_2OH) — drinking alcohol

Worked Example 2: Propanol (Two Isomers)

Isomer	Structure	Name	Use
1-propanol	$CH_3CH_2CH_2OH$ (OH on end carbon)	1-propanol	Solvent (less common)
2-propanol	$CH_3CH(OH)CH_3$ (OH on middle carbon)	Isopropanol / isopropyl alcohol	Rubbing alcohol

Worked Example 3: Acetic Acid (Vinegar)

Step	Analysis
Longest carbon chain	2 carbons → eth-
Functional group	-COOH (carboxylic acid) → suffix -oic acid
Name	Ethanoic acid (common name: acetic acid)

Worked Example 4: Gasoline Octane Rating

Teacher: *"Iso-octane (2,2,4-trimethylpentane) has a rating of 100 on the octane scale. It's highly branched, which makes it resist knocking in engines.*

- Normal heptane (straight chain C_7H_{16}) has a rating of 0. Gasoline's octane rating is the percentage of iso-octane in a mixture with heptane that has the same knocking characteristics."*

Partner talk (1 minute): *"Tell your partner: What is the IUPAC name for the molecule with 3 carbons and an -OH group on the middle carbon? (2-propanol or isopropanol)."*

SEGMENT 5: Organic Molecules in Everyday Life (10 minutes)

Teacher says: "Let's take a tour of the organic molecules you interact with daily."

Plastics (Polymers)

Polymer: A large molecule made of repeating smaller units called monomers.

Plastic	Monomer	Common Use	Recycling Code
PET (polyethylene terephthalate)	Ethylene glycol + terephthalic acid	Water bottles, soda bottles	♳ (1)
HDPE (high-density polyethylene)	Ethylene	Milk jugs, detergent bottles	♴ (2)
PVC (polyvinyl chloride)	Vinyl chloride	Pipes, shower curtains	♵ (3)
LDPE (low-density polyethylene)	Ethylene	Plastic bags, squeeze bottles	♶ (4)
PP (polypropylene)	Propylene	Yogurt cups, bottle caps	♷ (5)
PS (polystyrene)	Styrene	Foam cups, takeout containers	♸ (6)

Fats and Oils (Lipids)

Type	Structure	State at Room Temp	Examples
Saturated fat	Mostly single bonds (C-C)	Solid	Butter, coconut oil, lard
Unsaturated fat	Contains double bonds (C=C)	Liquid	Olive oil, canola oil, vegetable oil

Type	Structure	State at Room Temp	Examples
Trans fat	Double bonds in trans configuration	Solid (but unhealthy)	Partially hydrogenated oils (banned in many countries)

Teacher: "The C=C double bonds in unsaturated fats create kinks in the fatty acid chains, preventing them from packing tightly. That's why unsaturated oils are liquid at room temperature."

Carbohydrates (Sugars)

Sugar	Formula	Type	Where It's Found
Glucose	$C_6H_{12}O_6$	Monosaccharide (single sugar)	Fruit, blood sugar
Fructose	$C_6H_{12}O_6$	Monosaccharide	Fruit, honey (sweeter than glucose)
Sucrose	$C_{12}H_{22}O_{11}$	Disaccharide (glucose + fructose)	Table sugar, candy
Lactose	$C_{12}H_{22}O_{11}$	Disaccharide (glucose + galactose)	Milk
Starch	$(C_6H_{10}O_5)_n$	Polysaccharide (glucose polymer)	Potatoes, rice, bread

Medicines (Pharmaceuticals)

Medicine	Functional Groups	Action
Aspirin (acetylsalicylic acid)	Carboxylic acid (-COOH), ester (-COO-)	Pain relief, blood thinner
Ibuprofen (Advil, Motrin)	Carboxylic acid (-COOH)	Anti-inflammatory, pain relief
Acetaminophen (Tylenol)	Amide (-CONH-), phenol (-OH on aromatic ring)	Pain relief, fever reducer
Caffeine	Amine (-NH-), amide, alkene	Stimulant (coffee, tea, soda)

Teacher: "Medicines are organic molecules. Their shapes determine which receptors in your body they bind to, which determines their effect."

Partner talk (1 minute): "Tell your partner: What type of fat is liquid at room temperature? (Unsaturated — contains C=C double bonds)."

SEGMENT 6: Putting It All Together — Identifying Household Organics (8 minutes)

Teacher says: "Let's practice identifying organic molecules in common household products."

Mystery Compound 1

Clue	Analysis
Smells like fruit (banana)	Likely an ester
Used in candy flavoring	Isoamyl acetate
Formula: $C_7H_{14}O_2$	Contains -COO- ester group

Answer: Isoamyl acetate (banana flavoring).

Mystery Compound 2

Clue	Analysis
Sharp, sour smell	Carboxylic acid
Used in salad dressing	Vinegar
Formula: $C_2H_4O_2$	Contains -COOH group

Answer: Acetic acid (vinegar).

Mystery Compound 3

Clue	Analysis
Clear liquid, smell like markers or glue	Ketone or ester
Used to remove nail polish	Acetone or ethyl acetate
IR spectrum shows strong C=O peak (~5.8 μm) and C-O but no O-H	Ketone (no O-H)

Answer: Acetone (propanone — CH_3COCH_3).

Mystery Compound 4

Clue	Analysis
Solid at room temperature	Saturated fat or wax
Used in candles	Paraffin wax (long-chain alkane)
No functional groups — just C-C and C-H bonds	Alkane

Answer: Paraffin wax (mixture of long-chain alkanes, C_{20} to C_{40}).

CLOSING — The 60-Second Challenge (5 minutes)

Teacher says: "Pair up. Person A: 60 seconds — name four functional groups and give a household example of each. Person B: 60 seconds — explain why carbon can form millions of organic molecules (mention valence electrons and catenation)."

Final takeaway table (show on screen / read aloud):

You learned…	Household Example
Carbon can form 4 bonds (valence electrons = 4)	Carbon chains: methane (1 C) to decane (10 C)
Catenation = carbon bonds to itself	Long chains, branches, rings (plastics)
Alkanes = only C-C and C-H single bonds	Natural gas (methane), propane (grill)
Functional group = reactive part of molecule	Alcohol (-OH), carboxylic acid (-COOH), ester (-COO-)
Alcohols contain -OH	Rubbing alcohol (isopropanol), vodka (ethanol)
Carboxylic acids contain -COOH	Vinegar (acetic acid), lemons (citric acid)
Esters smell like fruit	Banana, apple, pineapple flavors
Saturated fats = single bonds (solid)	Butter, coconut oil
Unsaturated fats = double bonds (liquid)	Olive oil, canola oil
Sugars = carbohydrates ($C_nH_{2n}O_n$)	Glucose (fruit), sucrose (table sugar)
Plastics = polymers made from monomers	PET (water bottles), HDPE (milk jugs)

Final line (wrap-up of entire Level 2): "That's Level 2 — 13 lectures on the math and deeper science behind the chemistry in your home. You now know:

How to calculate atomic mass from isotopes

How to predict periodic trends

How to draw molecules and predict their shapes

How to balance chemical reactions

How to calculate moles and molar mass

How to calculate concentration and dilution

How to find pH and titrate acids

How to calculate heat and temperature changes

How to calculate half-life and decay

How to use gas laws (PV = nRT)

How to identify molecules with spectroscopy

How to recognize organic compounds in your home

You don't need a test or a grade. You just need to remember: chemistry is everywhere — and knowing the math behind it helps you make safer, smarter decisions."

SUPPLEMENTARY MATERIALS FOR L2-13 (No Grade)

Resource	Household Connection	Description	How to Find It
PhET "Molecule Shapes" simulation	Organic molecules	Build alkanes, see 3D shapes	Search "PhET molecule shapes"
Functional group flash cards	Study aid	Printable cards with examples	Search "functional groups flash cards"
Virtual organic chemistry model kit	3D visualization	Free online model kit	Search "molview"
Plastic recycling codes chart	Household recycling	Identify plastics by number	Search "plastic recycling symbols chart"

"This week, look at the ingredients on a food label or a medicine bottle. Find a word that ends in '-ol' (alcohol), '-ic acid' (carboxylic acid), or '-ate' (ester). Examples: citric acid, ascorbic acid, ethyl acetate. Next time, tell us what you found."

This completes Level 2 (Advanced Chemistry).