FORMALDEHYDE

IUPAC Name: Methanal

Chemical Formula: CH_2O

Molecular Weight: 30.03 g/mol

Appearance: Colorless gas with a strong, pungent odor

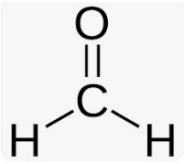
Boiling Point: -19 °C

Solubility: Soluble in water, alcohol, and ether

Commercial Solution: Known as formalin (usually 37–40% formaldehyde in water with methanol as a stabilizer)

Structure

Formaldehyde is the **simplest aldehyde**, consisting of one carbon atom double bonded to oxygen (carbonyl group) and single bonded to two hydrogen atoms.



Carbon is sp^2 hybridized

Geometry: Trigonal planar

Bond angles: ~120°

Highly **polar** molecule due to the electronegative oxygen atom

Properties

1. Highly reactive due to the carbonyl group
2. Acts as a strong reducing agent
3. Exhibits irritant and toxic properties upon inhalation or contact
4. Easily polymerizes to form paraformaldehyde or reacts with phenols, urea, and melamine to form resins

Preparation

1. Manufactured industrially by the oxidation of methanol

2. Naturally occurs in small amounts in the environment and in living organisms as a byproduct of metabolism

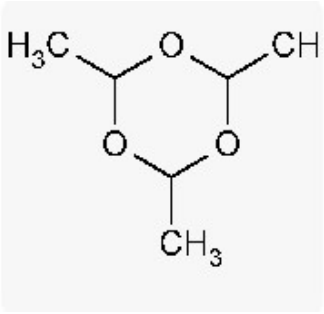
Applications

1. **Chemical Industry:** For production of resins (urea-formaldehyde, phenol-formaldehyde)
2. **Preservative:** In biological specimens and vaccines (in formalin form)
3. **Disinfectant & Germicide:** Due to its antimicrobial activity
4. **Textiles:** As an anti-wrinkle agent
5. **Laboratories:** As a reagent in qualitative tests and fixatives in microscopy
6. **Agriculture:** Used as a fumigant and fungicide

Toxicity and Hazards

1. Formaldehyde is **toxic** and classified as a **carcinogen**
2. Exposure can cause **eye, nose, throat, and skin irritation**
3. Prolonged exposure should be avoided; proper ventilation and protective equipment are recommended

PARALDEHYDE



Chemical Formula:	$C_6H_{12}O_3$
Molecular Weight:	132.16 g/mol
IUPAC Name:	2,4,6-Trimethyl-1,3,5-trioxane
Appearance:	Colorless to pale yellow liquid with a strong, characteristic odor
Boiling Point:	~124°C
Solubility:	Slightly soluble in water; miscible with alcohol, ether, and chloroform

Structure

Paraldehyde is a cyclic trimer of acetaldehyde. It is formed when three molecules of acetaldehyde undergo polymerization in the presence of acid.

Structural Features

- Cyclic compound with a **1,3,5-trioxane ring**
- Each carbon in the ring is bonded to a methyl group

Preparation

1. Formed by the acid-catalyzed polymerization of acetaldehyde
2. Reaction is reversible: paraldehyde can depolymerize back to acetaldehyde upon heating with dilute acid

Properties

1. Has sedative, hypnotic, and anticonvulsant properties
2. Volatile and flammable
3. Decomposes upon exposure to air and light, forming acetic acid and other irritants
4. Must be stored in airtight, amber-colored bottles

Uses

Medical Use

1. Formerly used as a sedative-hypnotic for insomnia and seizures
2. Used in treatment of alcohol withdrawal and status epilepticus
3. Administered orally or rectally (not commonly used now due to side effects and better alternatives)

Industrial Use

Used as a solvent in the manufacture of certain plastics and chemicals

Toxicity and Safety

1. CNS depressant in large doses
2. May cause **respiratory depression**, nausea, and liver damage
3. Irritating to eyes and mucous membranes
4. Should be used with caution; not recommended for long-term use

ACETONE

IUPAC Name: Propan-2-one

Common Name: Acetone

Chemical Formula: C_3H_6O

Molecular Weight: 58.08 g/mol

Appearance: Colorless, volatile liquid with a sweet, fruity odor

Structure of Acetone

- Acetone is the **simplest ketone**.
- It contains a **carbonyl group (C=O)** bonded to **two methyl groups**.

Structural Formula:

```
    O
    ||
CH3–C–CH3
```

1. Carbon in the carbonyl group is sp^2 hybridized
2. Molecule has planar geometry around the carbonyl carbon

Physical Properties

Property	Value/Description
1. **Boiling Point**	56 °C
2. **Melting Point**	-95 °C
3. **Solubility**	Completely miscible in water, alcohol, and ether
4. **Odor**	Sweet, fruity, characteristic smell
5. **Volatility**	Highly volatile and flammable

Preparation

1. **Industrial Method**

   Produced by the cumene process (also gives phenol as byproduct).

2. **Laboratory Method**

Can be prepared by **oxidation of isopropyl alcohol** using mild oxidizing agents like copper or potassium dichromate.

Chemical Properties

1. **Ketone Group:** Undergoes nucleophilic addition reactions
2. **Oxidation:** Oxidized to acetic acid
3. **Reactivity:** Reacts with hydrazine, hydroxylamine, and alcohols to form derivatives
4. **No reaction** with Tollen's or Fehling's reagent (distinguishes ketones from aldehydes)

Uses of Acetone

Field	Applications
Solvent	For paints, varnishes, nail polish remover, plastics
Cosmetics	In nail polish removers and skin treatments
Laboratories	As a cleaning agent and solvent
Industry	Used in manufacture of plastics (e.g., Plexiglass), synthetic fibers, drugs
Pharmaceuticals	Intermediate in chemical synthesis

Safety and Hazards

- **Highly flammable** – should be stored away from heat and flame
- Inhalation in large amounts may cause **dizziness, headache, or respiratory irritation**
- Use in **well-ventilated areas** and with proper protective equipment

CHLORAL HYDRATE

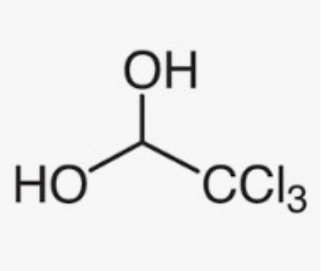
IUPAC Name:	2,2,2-Trichloro-1,1-ethanediol
Common Name:	Chloral hydrate
Chemical Formula:	$C_2H_3Cl_3O_2$
Molecular Weight:	165.40 g/mol
Appearance:	Colorless or white crystalline solid with a slightly bitter taste and pungent odor

Structure of Chloral Hydrate

1. Formed by hydration of chloral (trichloroacetaldehyde)
2. Contains a gem-diol (two hydroxyl groups on the same carbon) and three chlorine atoms

Structural Formula:

- Carbon attached to three chlorine atoms is also bonded to two hydroxyl groups
- It is a **hydrated aldehyde** structure (a geminal diol)



Preparation

Prepared by adding **water to chloral (CCl_3CHO)**, which is formed by chlorination of ethanol or acetaldehyde in the presence of a catalyst (e.g., sulfuric acid)

Physical Properties

	Property	Description
1.	**State**	Crystalline solid
2.	**Melting Point**	57 °C
3.	**Boiling Point**	Decomposes on heating
4.	**Solubility**	Soluble in water, alcohol, and ether
5.	**Taste**	Bitter and slightly caustic

Pharmacological Properties

- **Sedative-hypnotic:** Induces sleep and sedation

- **CNS depressant:** Slows down brain activity
- **Onset:** Acts within 30 minutes; lasts 6–8 hours
- **No analgesic effect**

Uses of Chloral Hydrate

Field	Application
Medicine	Formerly used as a **sedative-hypnotic**, **pre-anesthetic**, and **anticonvulsant**
Pediatric use	Occasionally used in children for **short-term sedation** (e.g., dental or imaging procedures)
Veterinary	Used in animal sedation and anesthesia
Chemistry	Intermediate in the synthesis of dyes and pesticides

Toxicity and Safety

1. Overdose may cause **respiratory depression**, **cardiac arrhythmias**, and **coma**
2. Long-term use can lead to **dependence** and **gastric irritation**
3. Use has declined due to safer alternatives like benzodiazepines
4. Should not be mixed with alcohol (can cause severe depression of CNS)

HEXAMINE

IUPAC Name: Hexamethylenetetramine

Common Name: Hexamine or Methenamine

Chemical Formula: $C_6H_{12}N_4$

Molecular Weight: 140.19 g/mol

Appearance: White crystalline solid with a faint ammonia-like odor

Structure of Hexamine

Hexamine is a heterocyclic organic compound formed by the reaction of formaldehyde and ammonia.

Structural Formula

- It consists of a **tetrahedral cage-like structure**.
- Each **nitrogen atom** is connected through **methylene (-CH_2-) bridges** to form a **polycyclic compound**.
- It is a **base** due to the lone pairs on nitrogen atoms.

Preparation

Hexamine is prepared industrially by the condensation reaction of ammonia and formaldehyde in a 4:6 molar ratio:

$4\ NH_3 + 6\ HCHO \rightarrow C_6H_{12}N_4 + 6\ H_2O$

Physical Properties

Property	Description
State	White crystalline powder
Melting Point	280 °C (decomposes)
Solubility	Soluble in water, alcohol
Stability	Stable under dry conditions; decomposes in acid

Chemical Properties

- **Acidic Hydrolysis:** In the presence of acids, it breaks down into **formaldehyde and ammonia**
- Acts as a **weak base**
- Forms salts with acids like **methenamine mandelate** and **methenamine hippurate** (used in urinary antiseptics)

Uses of Hexamine

Field	Application
Medicine	Used as **urinary antiseptic** (especially in acidic urine)
Explosives	Used in production of **RDX (Cyclonite)**, a powerful military explosive
Fuel Tablets	Used in **solid fuel tablets** for camping and military rations
Plastics Industry	Used in making **phenol-formaldehyde resins**
Rubber Industry	Used as an accelerator in the **vulcanization of rubber**
Pharmaceuticals	Intermediate in synthesis of various drugs

Safety and Toxicity

1. Generally **low toxicity**, but may cause irritation to the eyes, skin, or respiratory tract
2. Can release **formaldehyde** in acidic conditions, which is toxic
3. Should be handled with proper care in industrial environments

BENZALDEHYDE

IUPAC Name: Benzaldehyde

Common Name: Benzenecarbaldehyde

Chemical Formula: C_7H_6O

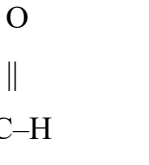
Molecular Weight: 106.12 g/mol

Appearance: Colorless to pale yellow liquid with a characteristic almond-like odor

Structure of Benzaldehyde

- Benzaldehyde consists of a **benzene ring** directly attached to an **aldehyde group (-CHO)**.

Structural Formula



$C_6H_5–C–H$

- The –CHO group is attached to a phenyl ring.
- The carbon of the –CHO group is sp^2 hybridized, making the molecule planar.
- Benzaldehyde is aromatic and reactive at the aldehyde group.

Physical Properties

	Property	Description
1.	**State**	Liquid
2.	**Boiling Point**	179 °C
3.	**Melting Point**	-26 °C
4.	**Odor**	Characteristic almond-like fragrance
5.	**Solubility**	Slightly soluble in water, miscible with alcohol and ether

Preparation of Benzaldehyde

1. **Laboratory Method:**

   Oxidation of benzyl alcohol using mild oxidizing agents like pyridinium chlorochromate.

2. **Industrial Method:**

   By oxidation of toluene or hydrolysis of benzal chloride.

Chemical Properties

1. **Does not reduce Fehling's or Tollen's reagent easily**, unlike aliphatic aldehydes.
2. Undergoes **electrophilic substitution** on the benzene ring.
3. Takes part in:

   Cannizzaro reaction (in absence of α-H)

   Nucleophilic addition reactions (e.g., with HCN)

   Condensation with amines, phenols, etc.

Uses of Benzaldehyde

Field	Applications
Flavouring Agent	Used to provide **almond flavor** in foods and beverages
Perfumery	Used in **fragrances and soaps** due to its sweet smell
Pharmaceuticals	Intermediate in the manufacture of drugs and dyes
Chemical Synthesis	Starting material for **dyes, perfumes, and resins**
Laboratory Reagent	For organic synthesis and as a reference standard

Toxicity and Safety

- **Moderately toxic** if ingested or inhaled in large quantities
- Can cause **irritation** to skin, eyes, and respiratory tract
- Should be handled in a well-ventilated area with protective gloves

VANILLIN

IUPAC Name: 4-Hydroxy-3-methoxybenzaldehyde

Common Name: Vanillin

Chemical Formula: $C_8H_8O_3$

Molecular Weight: 152.15 g/mol

Appearance: White to slightly yellow crystalline powder with a characteristic vanilla odor

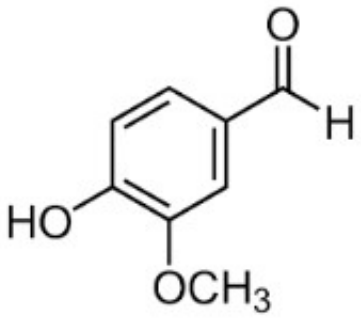
Structure of Vanillin

Vanillin is an **aromatic aldehyde** derived from **vanilla beans**. It has a **benzene ring** substituted with three functional groups:

- **–CHO (aldehyde group)** at position 1
- **–OH (hydroxyl group)** at position 4
- **–OCH_3 (methoxy group)** at position 3

Structural Formula

- Benzene ring with:
  - **–CHO** at para position to **–OH**
  - **–OCH_3** (methoxy) at meta position to **–CHO**



Physical Properties

Property	Description
State	Crystalline solid
Odor	Pleasant **vanilla-like fragrance**
Melting Point	81–83 °C
Boiling Point	285 °C (decomposes)
Solubility	Slightly soluble in water, soluble in alcohol and ether

Sources and Preparation

1. **Natural Source:**

   Extracted from **vanilla beans** (Vanilla planifolia)

Present in small quantities; natural vanillin is expensive

2. **Synthetic Production:**

   Industrially synthesized from:

   - **Guaiacol** (petrochemical derivative)
   - **Lignin** (wood pulp industry by-product)

Chemical Properties

- Reacts like an aromatic aldehyde:
  1. Undergoes nucleophilic addition at the –CHO group
  2. Undergoes electrophilic substitution on the aromatic ring
  3. Phenolic –OH can react with acids/bases
- Slightly acidic due to the phenol group

Uses of Vanillin

Field	Applications
Food Industry	Used as a **flavoring agent** in ice cream, chocolates, cakes
Perfumery	Used in making **perfumes and cosmetics**
Pharmaceuticals	As a **flavoring agent** in syrups and oral medications
Laboratory	Used as a **reagent** and intermediate in organic synthesis
Chemical Industry	Starting material for synthesis of fine chemicals

Safety and Toxicity

- Generally **recognized as safe (GRAS)** in food
- In large amounts, may cause mild irritation
- Non-toxic at concentrations used in food and fragrances

CINNAMALDEHYDE

IUPAC Name: (2E)-3-Phenylprop-2-enal

Common Name: Cinnamaldehyde

Chemical Formula: C_9H_8O

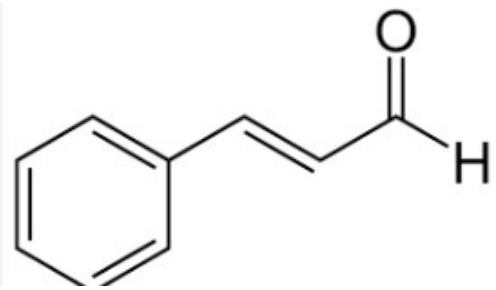
Molecular Weight: 132.16 g/mol

Appearance: Yellow to pale yellow oily liquid with a strong cinnamon-like odor

Structure of Cinnamaldehyde

Cinnamaldehyde is an α,β-unsaturated aromatic aldehyde, consisting of:

- A **benzene ring (phenyl group)**
- A **conjugated double bond (–CH=CH–)**
- An **aldehyde group (–CHO)**



Structural Formula:

C6H5–CH=CH–CHO

- The double bond and aldehyde group are in **conjugation** with the benzene ring.
- Exists predominantly in the **trans (E) isomer**, which is more stable and naturally occurring.

Physical Properties

Property	**Description**
1. **State**	Oily liquid
2. **Odor**	Sweet, **spicy cinnamon-like smell**
3. **Boiling Point**	~248 °C
4. **Melting Point**	-7.5 °C
5. **Solubility**	Slightly soluble in water, miscible in alcohol and organic solvents

Source and Preparation

- **Natural Source:**

Extracted from cinnamon bark oil (Cinnamomum species)

Makes up **~60–75% of cinnamon oil**

- **Synthetic Preparation:**

  By **aldol condensation** of **benzaldehyde** and **acetaldehyde**

Chemical Properties

- Contains both **aromatic** and **α,β-unsaturated aldehyde** functional groups
- Undergoes:
  1. **Nucleophilic addition** reactions at –CHO group
  2. **Electrophilic aromatic substitution** on the benzene ring
  3. **Reduction** to cinnamyl alcohol or hydrocinnamaldehyde
  4. **Oxidation** to cinnamic acid

Uses of Cinnamaldehyde

Field	Applications
Flavoring Agent	Used in food and beverages for **cinnamon flavor**
Perfumery	Used in soaps, cosmetics, and perfumes
Pharmaceuticals	Mild antifungal, antimicrobial agent; used in some mouthwashes
Agriculture	Acts as a natural **pesticide and fungicide**
Chemical Industry	Intermediate in organic synthesis

Safety and Toxicity

1. Generally safe in small quantities as a food additive (GRAS status by FDA)
2. High concentrations may cause:
   a. Skin and mucous membrane **irritation**
   b. Allergic reactions in sensitive individuals
3. Handle with gloves and proper ventilation in industrial settings