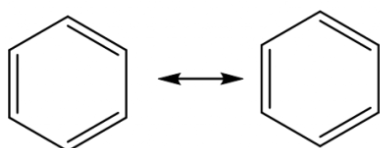


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## 8.4 Aromatic Compounds: Benzene

Next we consider a class of hydrocarbons with molecular formulas like those of unsaturated hydrocarbons, but which, unlike the alkenes, do not readily undergo addition reactions. These compounds comprise a distinct class, called aromatic hydrocarbons. Aromatic hydrocarbons are compounds that contain a benzene ring structure. The simplest aromatic compound is benzene ( $C_6H_6$ ) and it is of great commercial importance, but it also has noteworthy deleterious health effects (see “To Your Health: Benzene and Us”).

The formula  $C_6H_6$  seems to indicate that benzene has a high degree of unsaturation. (Hexane, the saturated hydrocarbon with six carbon atoms has the formula  $C_6H_{14}$ — eight more hydrogen atoms than benzene.) However, despite the seeming low level of saturation, benzene is rather unreactive. This is due to the resonance structure formed from the alternating double bond structure of the aromatic ring.



The benzene ring structure is stabilized by resonance. One of the few reactions that benzene rings will undergo are substitution reactions.

### Note

Benzene is a liquid that smells like gasoline, boils at  $80^\circ C$ , and freezes at  $5.5^\circ C$ . It is the aromatic hydrocarbon produced in the largest volume. It was formerly used to decaffeinate coffee and was a significant component of many consumer products, such as paint strippers, rubber cements, and home dry-cleaning spot removers. It was removed from many product formulations in the 1950s, but others continued to use benzene in products until the 1970s when it was associated with leukemia deaths. Benzene is still important in industry as a precursor in the production of plastics (such as Styrofoam and nylon), drugs, detergents, synthetic rubber, pesticides, and dyes. It is used as a solvent for such things as cleaning and maintaining printing equipment and for adhesives such as those used to attach soles to shoes. Benzene is a natural constituent of petroleum products, but because it is a known carcinogen, its use as an additive in gasoline is now limited.

### To Your Health: Benzene and Us

Most of the benzene used commercially comes from petroleum. It is employed as a starting material for the production of detergents, drugs, dyes, insecticides, and plastics. Once widely used as an organic solvent, benzene is now known to have both short- and long-term toxic effects. The inhalation of large concentrations can cause nausea and even death due to respiratory or heart failure, while repeated exposure leads to a

progressive disease in which the ability of the bone marrow to make new blood cells is eventually destroyed. This results in a condition called *aplastic anemia*, in which there is a decrease in the numbers of both the red and white blood cells.

### Concept Review Exercises

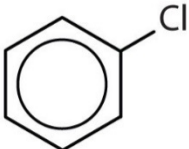
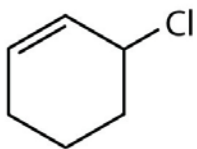
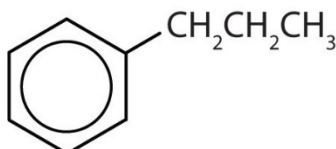
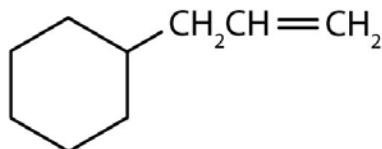
1. How do the typical reactions of benzene differ from those of the alkenes?
2. Briefly describe the bonding in benzene.
3. What does the circle mean in the chemist's representation of benzene?

### Answers

1. Benzene is rather unreactive toward addition reactions compared to an alkene.
2. Valence electrons are shared equally by all six carbon atoms (that is, the electrons are delocalized).
3. The six electrons are shared equally by all six carbon atoms.

### Recognizing Aromatic Compounds

Which compounds are aromatic?

1. 
2. 
3. 
4. 

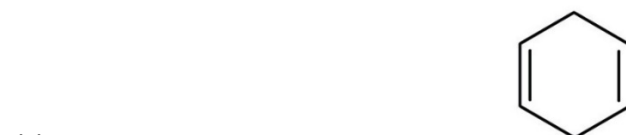
### Solution

5. The compound has a benzene ring (with a chlorine atom substituted for one of the hydrogen atoms); it is aromatic.

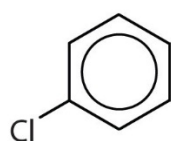
6. The compound is cyclic, but it does not have a benzene ring; it is not aromatic.
7. The compound has a benzene ring (with a propyl group substituted for one of the hydrogen atoms); it is aromatic.
8. The compound is cyclic, but it does not have a benzene ring; it is not aromatic.

### Skill-Building Exercise

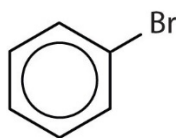
Which compounds are aromatic?



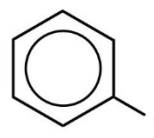
In the International Union of Pure and Applied Chemistry (IUPAC) system, aromatic hydrocarbons are named as derivatives of benzene. Five examples are shown below. In these structures, it is immaterial whether the single substituent is written at the top, side, or bottom of the ring: a hexagon is symmetrical, and therefore all positions are equivalent.



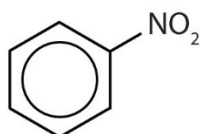
Chlorobenzene



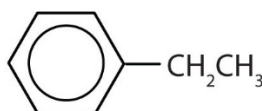
Bromobenzene



Iodobenzene



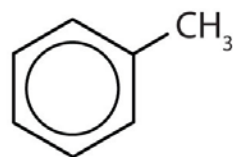
Nitrobenzene



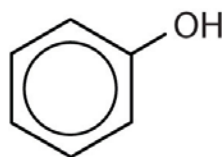
Ethylbenzene

These compounds are named in the usual way with the group that replaces a hydrogen atom named as a substituent group: Cl as chloro, Br as bromo, I as iodo, NO<sub>2</sub> as nitro, and CH<sub>3</sub>CH<sub>2</sub> as ethyl.

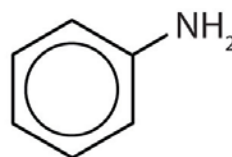
Although some compounds are referred to exclusively by IUPAC names, some are more frequently denoted by common names, as is indicated below.



Toluene



Phenol



Aniline

### **Key Takeaway**

- Aromatic hydrocarbons appear to be unsaturated, but they have a special type of bonding and do not undergo addition reactions.

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