# Organic Chemistry

## Reactions of Alkanes: Combustion, Elimination & Substitution
## Reactions of Alkenes: Addition, Hydrogenation, Polymerization

# Alkanes

- Alkanes are non-polar, non-reactive hydrocarbons
- Why are they non-polar?
  - The electronegativity difference between C and H is quite close, meaning they share electrons fairly evenly. There is no dipole to attract ionic species
- Why are they unreactive?
  - The bond enthalpies for C-C bonds and C-H bonds are relatively high (348,412kJ/mol respectively), making the bonds quite tough to break

# Alkanes

- When we combine the two (high bond enthalpy and being non-polar) this makes alkanes quite unreactive
  - Alkanes don't react with acids/bases or oxidizing agents
- This is a useful trait and alkanes are used as lubricating agents and the backbone of polymers
- But when the do react – Look out!

# Combustion of Alkanes

- When there is sufficient oxygen, alkanes will burn and form water and carbon dioxide as products

- Try it: Write the complete combustion reaction of butane

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g) \quad \Delta H = -5754\ \text{kJ mol}^{-1}$$

- In general, the formula for complete combustion of alkanes is:

$$C_xH_y(g) + \left(x + \frac{y}{4}\right)O_2(g) \rightarrow xCO_2(g) + \frac{y}{2}H_2O(g)$$

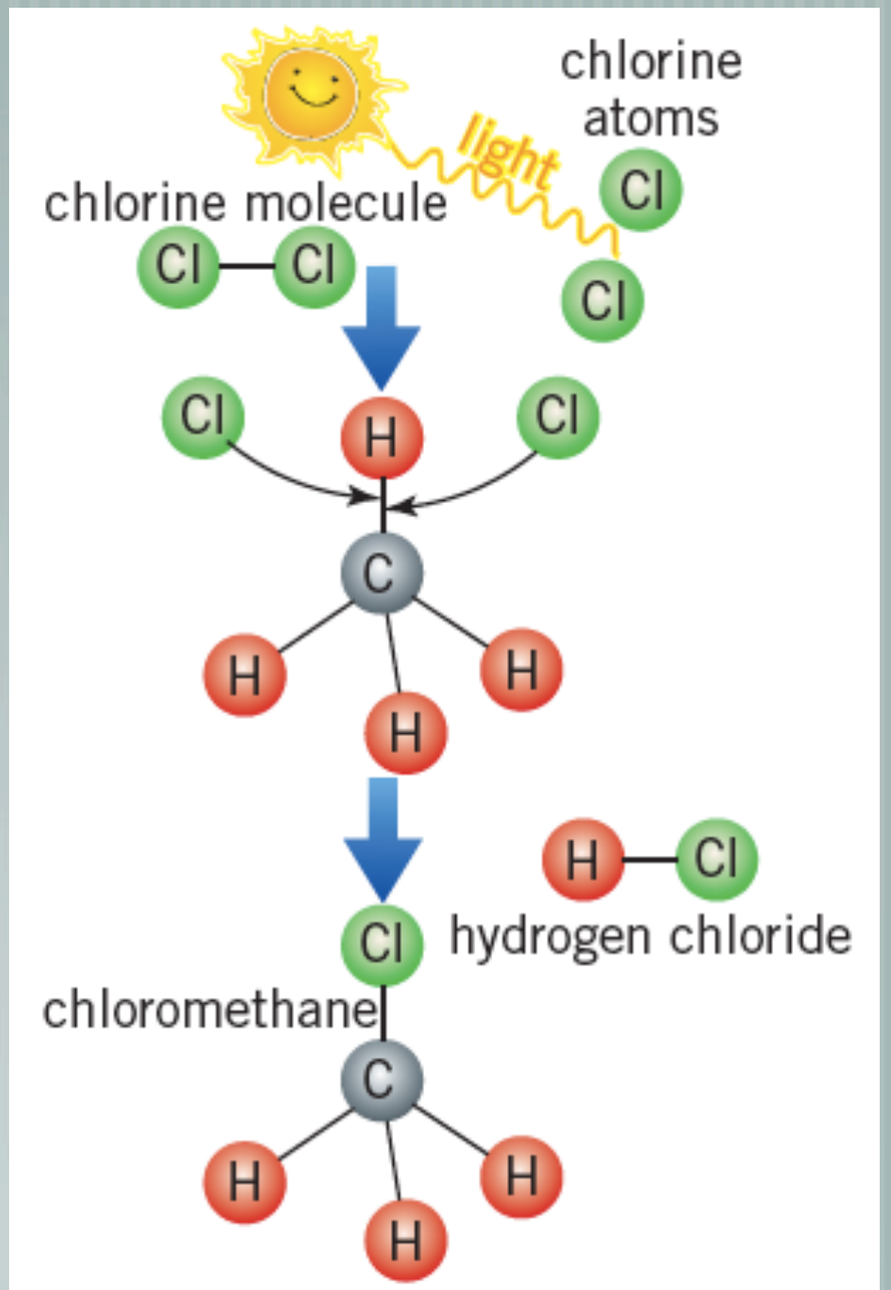
# What if there isn't enough $O_2$?

- Then we have **incomplete** combustion where carbon monoxide and elemental carbon are formed

- Both are toxic (CO interferes with oxygen transport, elemental C is soot and aggravates asthma)
- Incomplete combustion of octane: $2C_8H_{18}(l) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(g)$

# Substitution Reactions

- In a substitution reaction a halogen replaces a hydrogen in an alkane
- In this reaction, two bonds must be broken:
  - C-H & the bond between the halogens
- We will look at each step in sequence (the mechanism by which this reaction occurs)

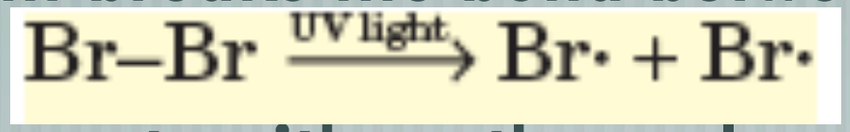


# Substitution Reactions

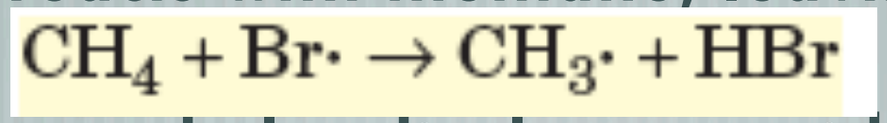
- Since the sharing of electrons between $Cl_2$ (or any halogen, like Br) is even, when it splits it and an electron goes to each Cl• during a process called "Homolytic fission"
- Cl• contains an unpaired electron & is called a "free radical"
- Free radicals are very reactive and often go on to create more free radicals

# Mechanism

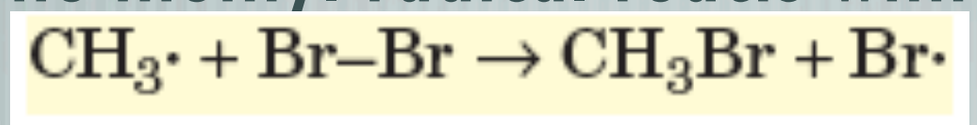
- Let's look at the mechanism behind the substitution reaction of bromine reacting with methane
- Initiation: UV light breaks the bond between $Br_2$ leaving free radicals



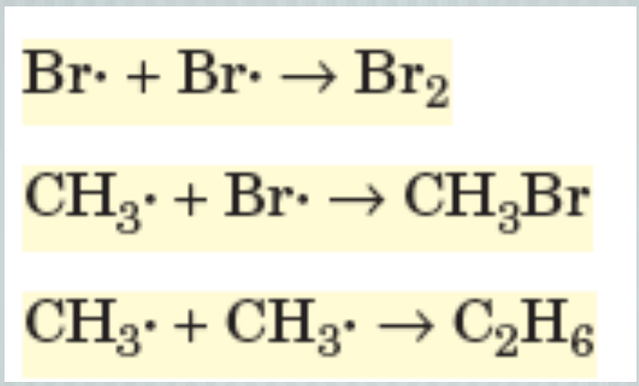

- Propagation: Br reacts with methane, leaving another radical




- Propagation: The methyl radical reacts with another bromine molecule




- Termination: Two radicals react and complete the reaction




* Lots of Bromine will mean more substitution (dibromo, tribromo, etc)

# Try it

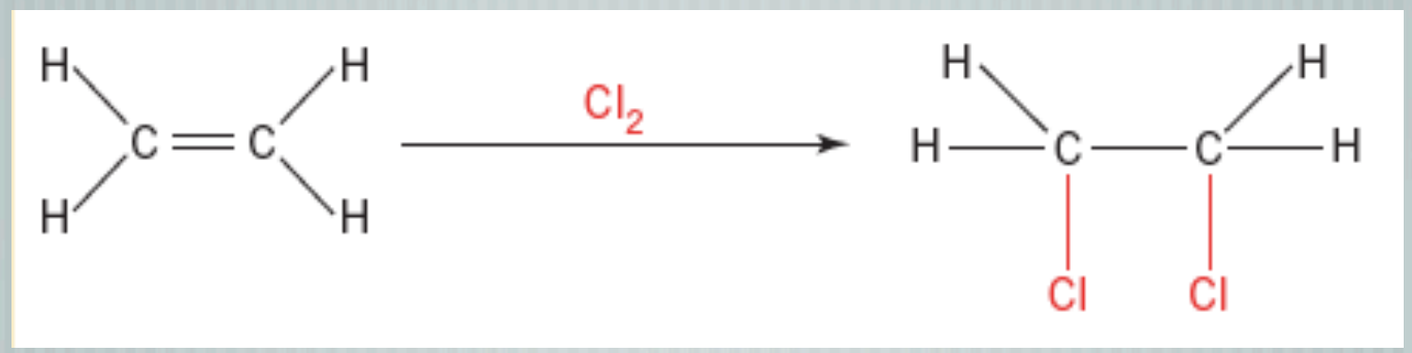
## Write the mechanism for ethane reacting with $Cl_2$

# Importance of Alkenes

- Alkenes are very important in society. They much more reactive than alkanes because of the double bond present
- They are created by "cracking" alkanes
- Alkenes are the building blocks for many polymers, including most plastics
- Alkenes are also important in many food products, like butter & margarine

# Addition Reactions

- The double bond is the most reactive part of alkene and it is where a reaction will occur
- The double bond will break and the halogen will attach on either side of carbons that used to have the double bond
- Name these compounds:



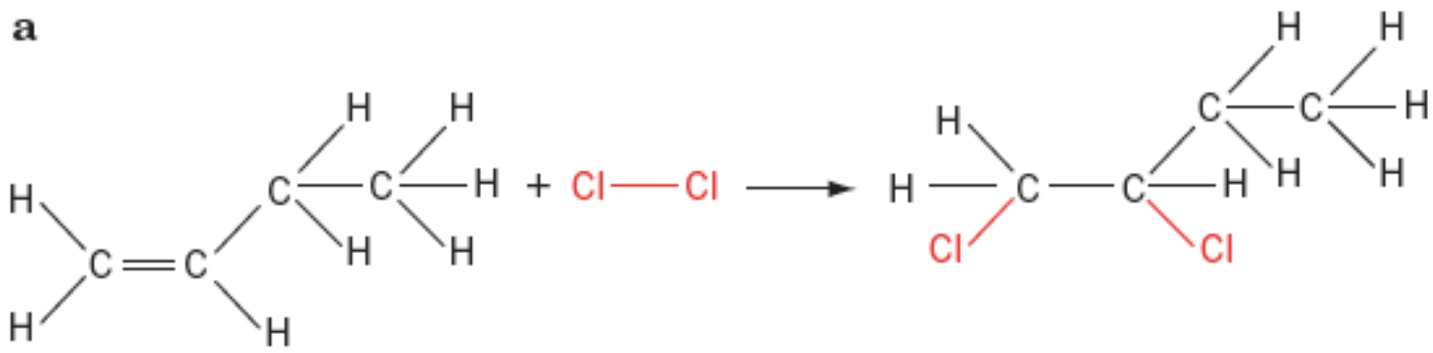
# Try it!

State the products of the reaction with chlorine of:

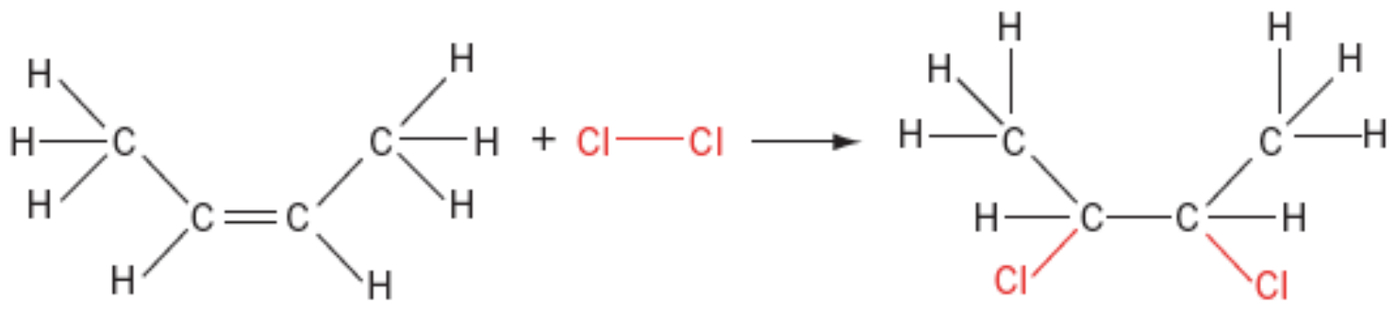
**a** but-1-ene

**b** but-2-ene.

**a**

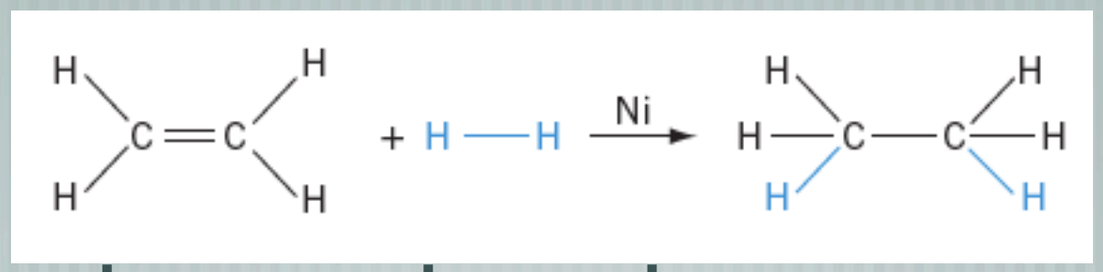


**b**



# Hydrogenation

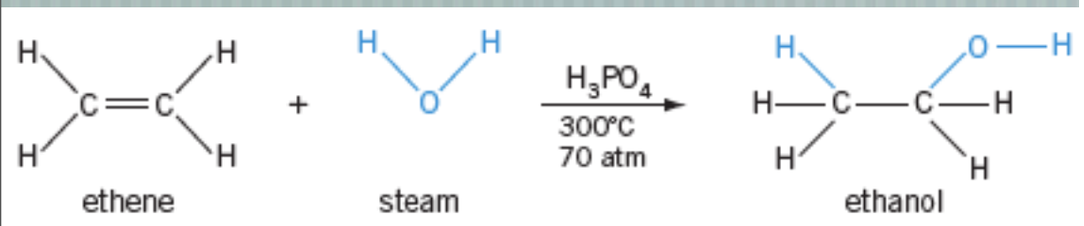
- Hydrogenation is a specific type of addition where the alkene is reacting with hydrogen instead of with a halogen
- Usually requires the presence of a catalyst



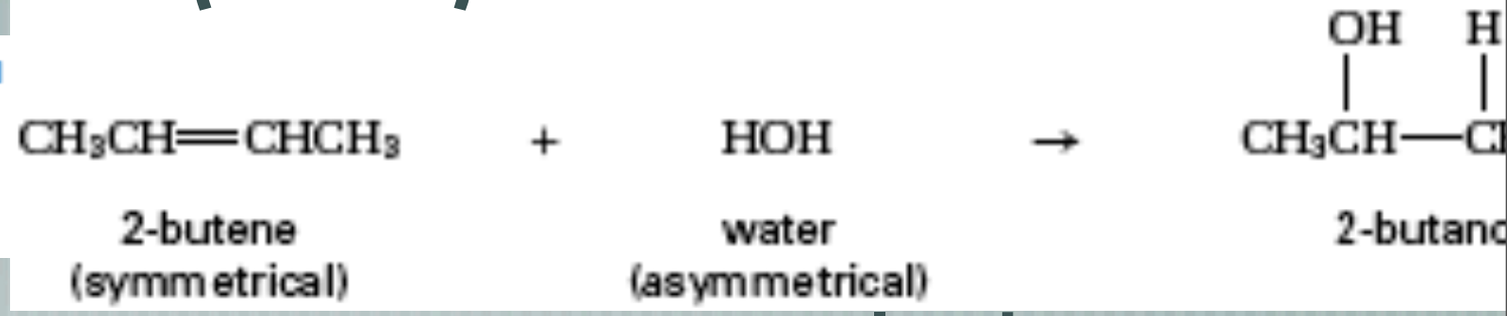

- This is the process that is used to make margarine: margarine is made from vegetable oil (contains polyunsaturated fats) but you can't "spread" oil, so it is partially hydrogenated to make it harder and more spreadable

# Reactions of hydrogen halides

- Other compounds can be added to alkenes, such as hydrogen halides (ie H - Cl) or water (H - OH)

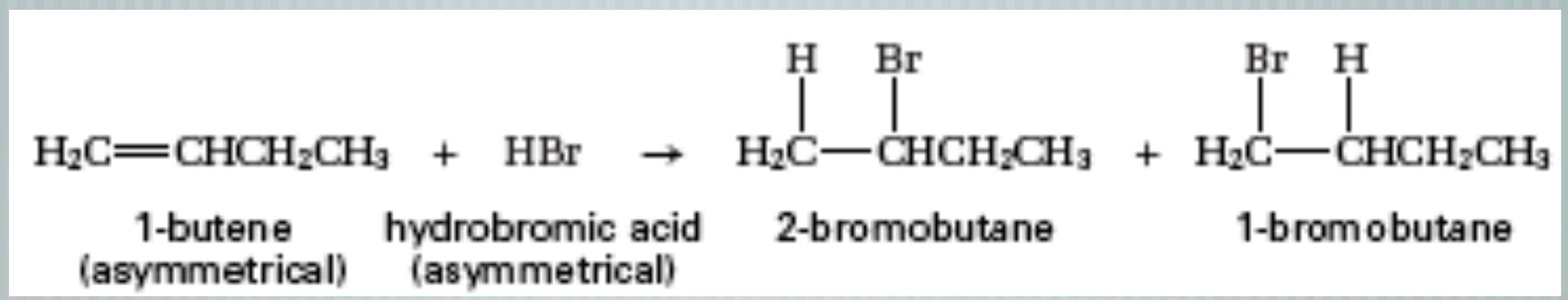



ethene steam ethanol




2-butene (symmetrical) water (asymmetrical) 2-butanol

- What about if both reactants are asymmetrical? Then we have 2 possible products and have to decide which is more likely to be formed




1-butene (asymmetrical) hydrobromic acid (asymmetrical) 2-bromobutane 1-bromobutane

# Markovnikov's Rule

Markovnikov's rule states that **"the rich get richer"**. This means that the more substituted carbon (carbon already attached to more functional groups (like OH or a halogen) will get the functional group: OH or a halogen)

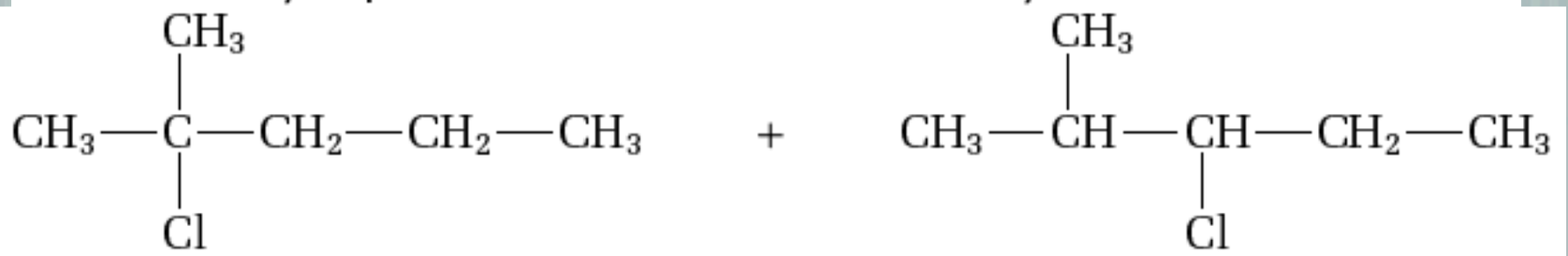
# Try it!

Complete this reaction and determine which product will be more likely produced.

2-methyl-2-pentene + hydrochloric acid →?

2-methyl-2-pentene + HCl →

2-methyl-2-pentene hydrochloric acid



2-chloro-2-methylpentane (major product) + 3-chloro-2-methylpentane (minor product)

# Try it!

Name the reactants and products of each reaction. Use Markovnikov's rule to predict which of the two products will form in the greater amount.

**(a)** $CH_2{=}CHCH_2CH_2CH_2CH_3 + HBr \rightarrow$

. Draw the major product of each reaction.

**(a)** $CH_3CH{=}CH_2 + Br_2 \rightarrow$

**(b)** $CH_2{=}CH_2 + HOH \rightarrow$

**(c)** $CH_2{=}CHCH_2CH_3 + HBr \rightarrow$

**(d)** $(CH_3)_2C{=}CHCH_2CH_2CH_3 + HCl \rightarrow$

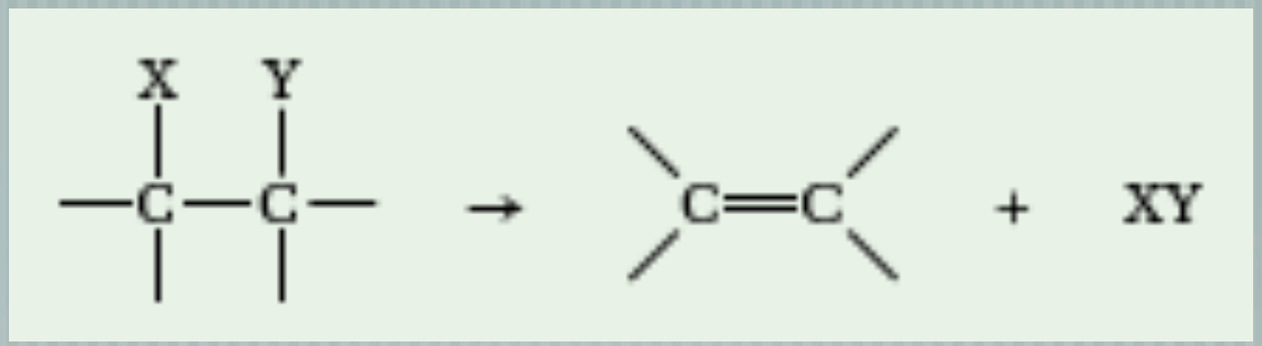
# Challenge!

In violation of safety rules, you are eating a bacon cheeseburger near a sample of $Br_2$ dissolved in water (commonly called bromine water). The bromine water has a yellow/orange colour. Some bacon falls out of your sandwich and falls into the bromine. The bromine water slowly loses its brown colour. Explain what reaction is happening.

# Answer!

- Bacon contains fats, which include unsaturated fats. Unsaturated fats (alkenes) react with the bromine water, forming haloalkanes. This removes the bromine from the water and it looses colour.

# Elimination Reactions

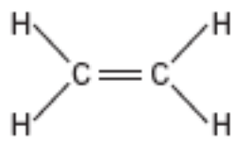
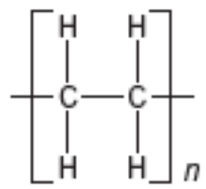
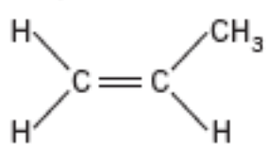
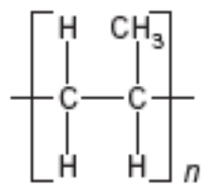
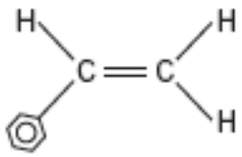
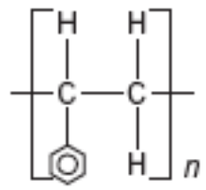
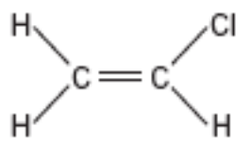
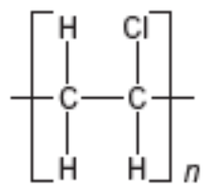



- In an elimination reaction, an alkane can be made into an alkene
- This is the reverse of addition

# Polymerization of Alkenes

- Poly means "many"
- Naming is usually just adding "poly" in front of the original monomer
- Polymers often result in new unique properties that become very useful.

**TABLE 11.4.1 A SELECTION OF ADDITION POLYMERS MADE USING MONOMERS DERIVED FROM ETHENE**

| Monomer | Polymer | Polymer name | Some uses |
|---|---|---|---|
| Ethene  |  | Poly(ethene) | Plastic bags, bottles, toys |
| Propene  |  | Poly(propene) | Indoor–outdoor carpeting, bottles, luggage |
| Styrene  |  | Poly(styrene) | Styrofoam insulation, cups, packing materials |
| Chloroethene  |  | Poly(chloroethene) or polyvinyl chloride (PVC) | Plastic wrap, plumbing, garden hoses |

# Try it!

**1** **a** Give balanced equations for each of the following reactions.

**i** Reaction between but-2-ene and hydrogen

**ii** Addition of bromine to ethene

**iii** Complete combustion of ethanol

**iv** Reaction between ethane and chlorine

**b** State any conditions necessary for the reaction in part **a iv**.

**c** What would you observe during the reaction in part **a ii**?

**2** Using any non-organic reagents necessary, show how you would prepare the following chlorinated hydrocarbons.

**a** Chloroethane from ethane

**b** Chloroethane from ethene

**3** Describe the test that indicates whether a hydrocarbon is saturated or unsaturated.

**4** 5.91 g of chlorine gas reacts with exactly 2.33 g of a pure alkene according to the equation:

$C_nH_{2n} + Cl_2 \rightarrow C_nH_{2n}Cl_2$

**a** What is the name given to this type of reaction?

**b** Determine the molecular formula of the alkene.

**5** Give the structural formulas of possible 'dibromo-' compounds that could be formed from the reaction of bromine with:

**a** ethane

**b** ethene.

**6** **a** State an equation for the hydration of ethene.

**b** State the conditions required for the reaction in part **a** to occur.

**c** Write the equation for the reaction between ethene and HCl.

**7** Explain what is meant by the term *polymer*.

**8** State the balanced chemical equations for the formation of the following polymers:

**a** polyethene

**b** polypropene