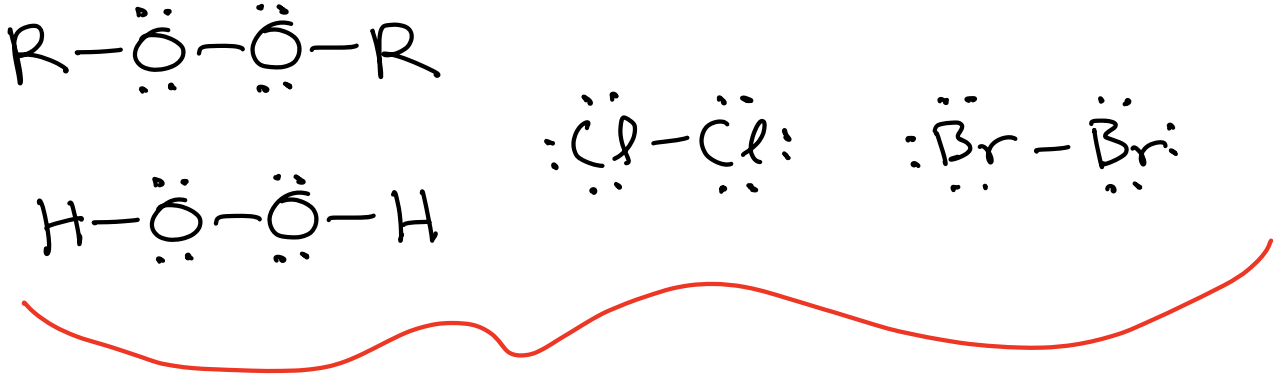
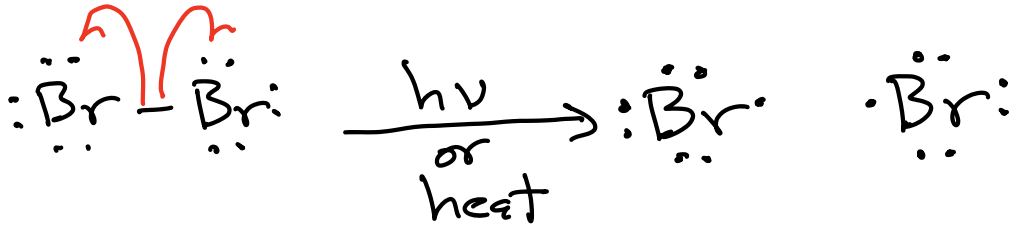

Energizer

Bonds between atoms with multiple pairs are generally weaker bonds → lone pairs repel each other

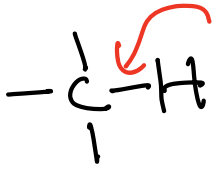


These bonds can be broken by light or heat

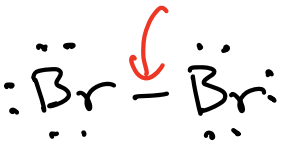
"hν"



Reference bond strengths



BDE ~100 kcal/mol

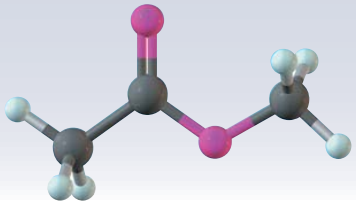


BDE ~46 kcal/mol

Bond Dissociation Enthalpies

The amount of energy required to break a bond

Appendix 3 Bond Dissociation Enthalpies



Bond dissociation enthalpy (BDE) is defined as the amount of energy required to break a bond homolytically into two radicals in the gas phase at 25°C.

$$A—B \rightarrow A\cdot + B\cdot \qquad \Delta H^0 \text{ [kJ (kcal)/mol]}$$

Bond	ΔH^0	Bond	ΔH^0	Bond	ΔH^0
H—H bonds		**C—C multiple bonds**		**C—Br bonds**	
H—H	435 (104)	CH_2═CH_2	727 (174)	CH_3—Br	301 (72)
D—D	444 (106)	HC≡CH	966 (231)	C_2H_5—Br	301 (72)
				$(CH_3)_2CH$—Br	309 (74)
X—X bonds		**C—H bonds**		$(CH_3)_3C$—Br	305 (73)
F—F	159 (38)	CH_3—H	439 (105)	CH_2═$CHCH_2$—Br	247 (59)
Cl—Cl	247 (59)	C_2H_5—H	422 (101)	C_6H_5—Br	351 (84)
Br—Br	192 (46)	$(CH_3)_2CH$—H	414 (99)	$C_6H_5CH_2$—Br	263 (63)
I—I	151 (36)	$(CH_3)_3C$—H	405 (97)		
		CH_2═CH—H	464 (111)	**C—I bonds**	
H—X bonds		CH_2═$CHCH_2$—H	372 (89)	CH_3—I	242 (58)
H—F	568 (136)	C_6H_5—H	472 (113)	C_2H_5—I	238 (57)
H—Cl	431 (103)	$C_6H_5CH_2$—H	376 (90)	$(CH_3)_2CH$—I	238 (57)
H—Br	368 (88)	HC≡C—H	556 (133)	$(CH_3)_3C$—I	234 (56)
H—I	297 (71)			CH_2═$CHCH_2$—I	192 (46)
		C—F bonds		C_6H_5—I	280 (67)
O—H bonds		CH_3—F	481 (115)	$C_6H_5CH_2$—I	213 (51)
HO—H	497 (119)	C_2H_5—F	472 (113)		
CH_3O—H	439 (105)	$(CH_3)_2CH$—F	464 (111)	**C—N single bonds**	
C_6H_5O—H	376 (90)	C_6H_5—F	531 (127)	CH_3—NH_2	355 (85)
				C_6H_5—NH_2	435 (104)
O—O bonds		**C—Cl bonds**			
HO—OH	213 (51)	CH_3—Cl	351 (84)	**C—O single bonds**	
CH_3O—OCH_3	159 (38)	C_2H_5—Cl	355 (85)	CH_3—OH	385 (92)
$(CH_3)_3CO$—$OC(CH_3)_3$	159 (38)	$(CH_3)_2CH$—Cl	355 (85)	C_6H_5—OH	468 (112)
		$(CH_3)_3$ C—Cl	355 (85)		
C—C single bonds		CH_2═$CHCH_2$—Cl	288 (69)		
CH_3—CH_3	376 (90)	C_6H_5—Cl	405 (97)		
C_2H_5—CH_3	372 (89)	$C_6H_5CH_2$—Cl	309 (74)		
CH_2═CH—CH_3	422 (101)				
CH_2═$CHCH_2$—CH_3	322 (77)				
C_6H_5—CH_3	435 (104)				
$C_6H_5CH_2$—CH_3	326 (78)				

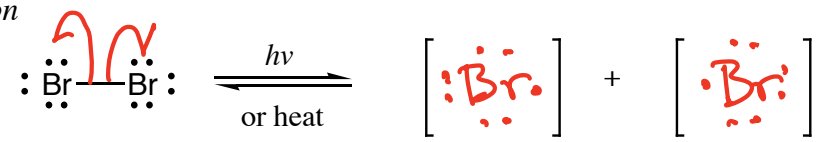
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Not For Sale

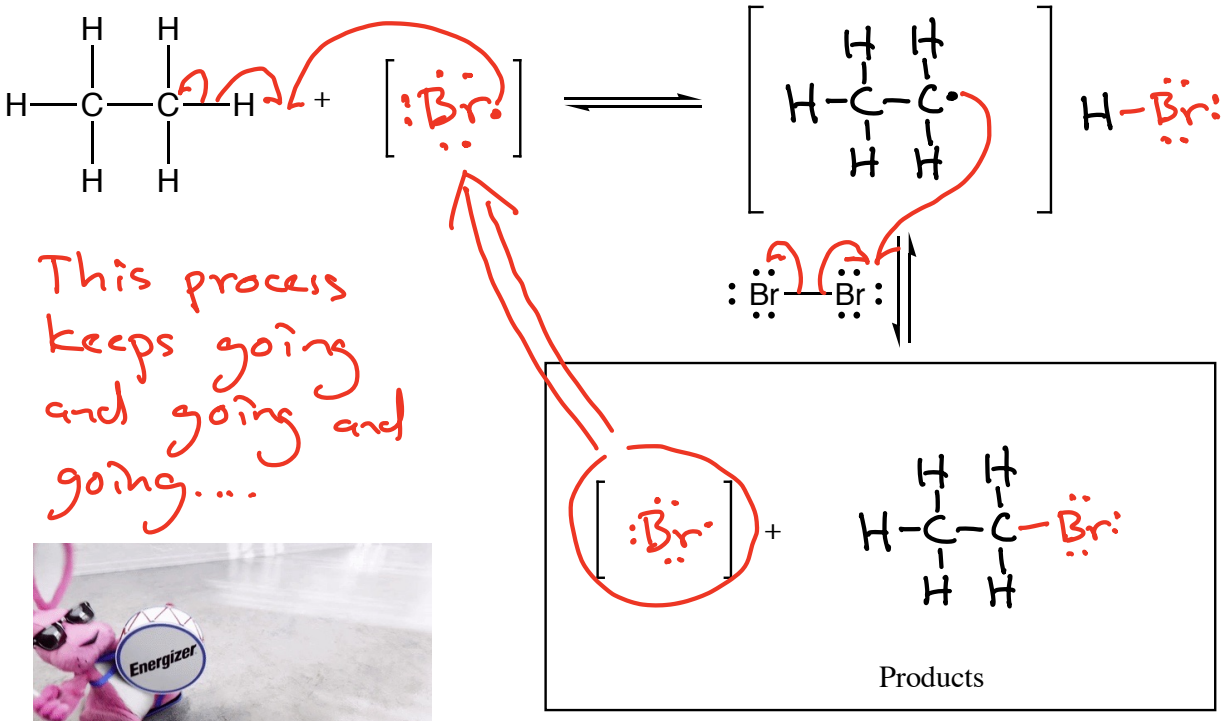
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Alkane Free Radical Halogenation

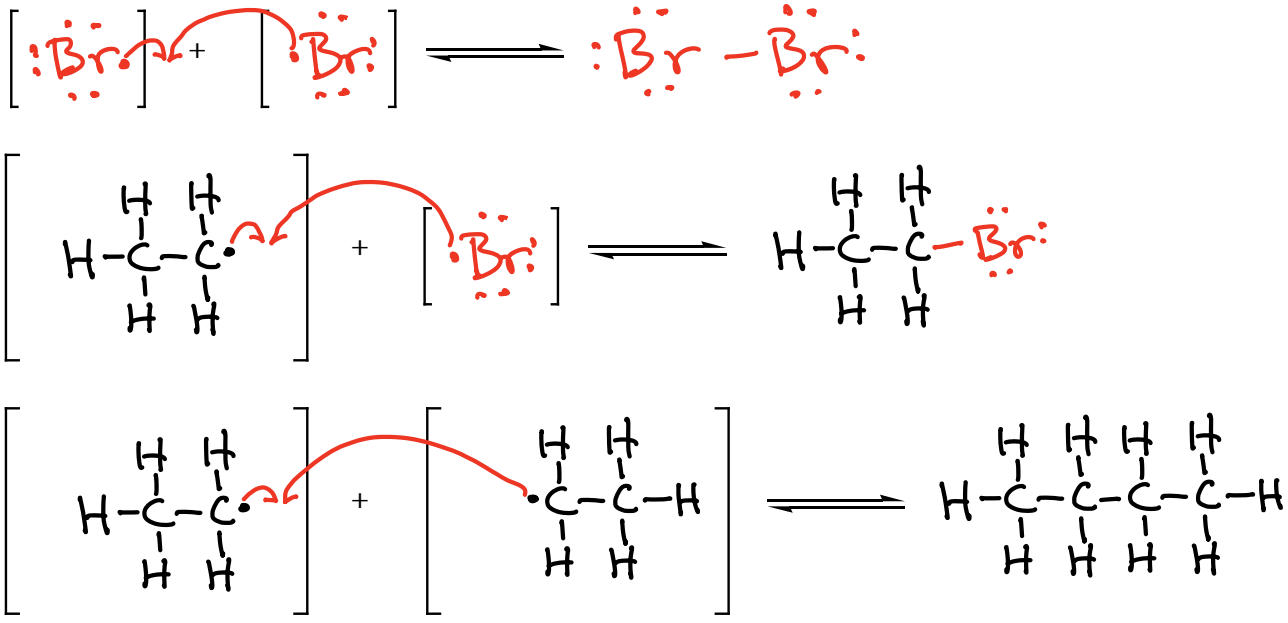
Initiation



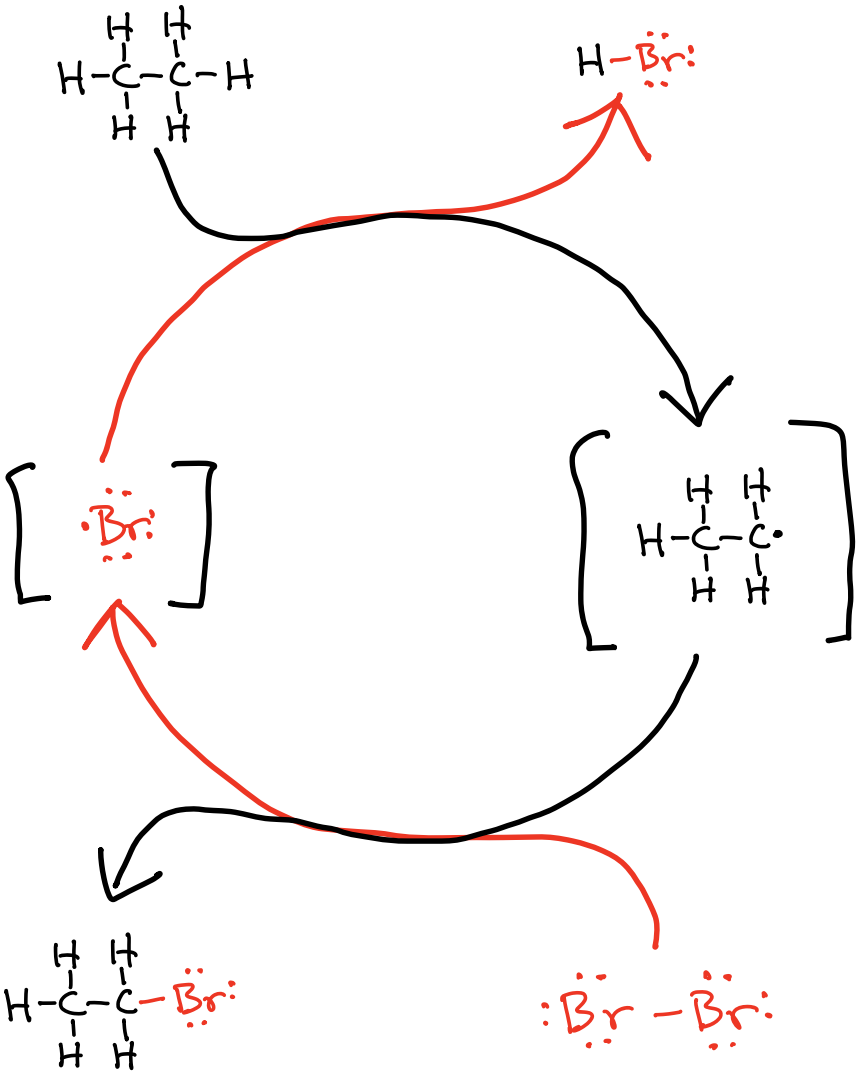
Propagation



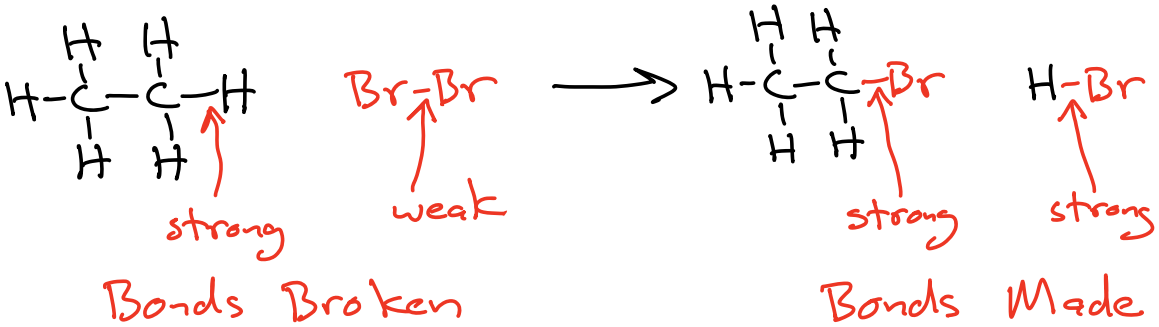
Termination



Propagation Process Diagram



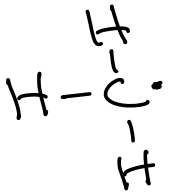
Motive for overall process



$$\text{Alkane} \xrightarrow[\substack{h\nu \\ \text{or} \\ \text{heat}}]{Br_2} \text{Haloalkane}$$

This is the only reaction you will learn that starts with an alkane

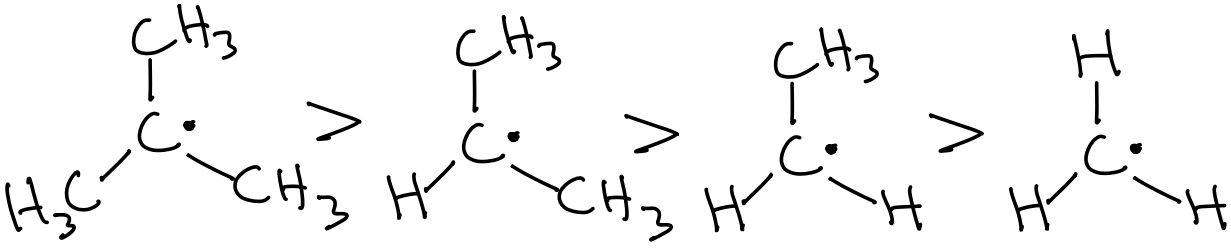
Radical → species with an unpaired electron → very reactive → we only see these as a reaction intermediate



← Neutral (no charge!)

⇒ Think of a radical as being "analogous to a carbocation"

- → sp^2 hybridized with the unpaired electron in the 2p orbital
- → Alkyl groups stabilize radicals through hyperconjugation



← Radical Stability

<u>Organic Chemistry</u> is the study of carbon-containing molecules.

This class has two points.

The first point of the class is to understand the organic chemistry of living systems. We will teach you how to think about and understand the most amazing things on the planet!!

Water is essential for life, you will learn why water has such special properties. 8/25/26

You will learn the secret structural reason proteins, the most important molecular machines in our bodies, can support the chemistry of life. 9/9/26

You will learn why when you take Advil for pain, exactly half of what you take works, and the other half does nothing.

You will learn how toothpaste works. 9/21/26 9/30/26

You will learn how a single chlorofluorocarbon refrigerant molecule released into the atmosphere can destroy many, many ozone molecules, leading to an enlargement of the ozone hole. 10/26/26

You will learn how medicines like Benadryl, Seldane, and Lipitor work.

You will learn how Naloxone is an antidote for an opioid overdose.

You will learn why Magic Johnson is still alive, decades after contracting HIV.

You will learn how MRI scans work.

The second point of organic chemistry is the synthesis of complex molecules from simpler ones by making and breaking specific bonds.

You will learn how to understand movies of reaction mechanisms like alkene hydration. 10/5/26

You will learn reactions that once begun, will continue reacting such that each product molecule created starts a new reaction until all the starting material is used up. 10/26/26

You will learn reactions that can make antifreeze from vodka.

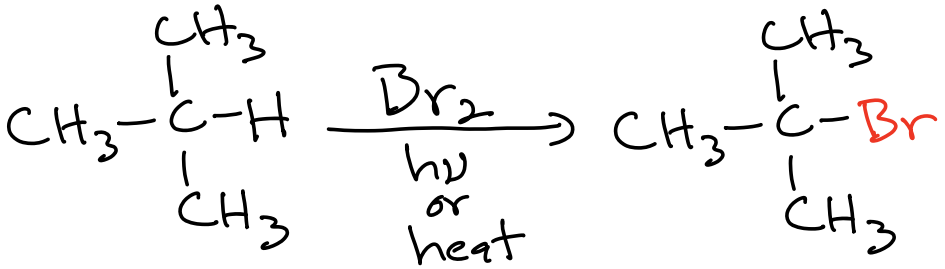
You will learn a reaction that can make nail polish remover from rubbing alcohol.

You will learn how to look at a molecule and accurately predict which atoms will react to make new bonds, and which bonds will break during reactions.

You will learn how to analyze a complex molecule's structure so that you can predict ways to make it via multiple reactions starting with less complex starting molecules.

★ ⇒ When there is a choice in a radical reaction with an alkane, the Br atom will end up on the most substituted C atom(s) in the molecule

Reason ⇒ More stable radicals form more easily



Br_2 is more selective than Cl_2 so always use Br_2

Hammond's Postulate

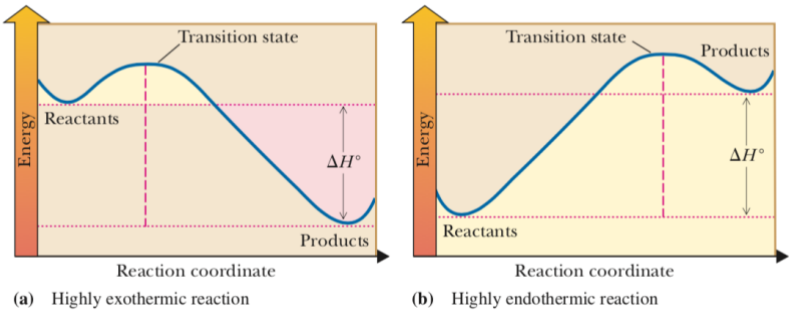
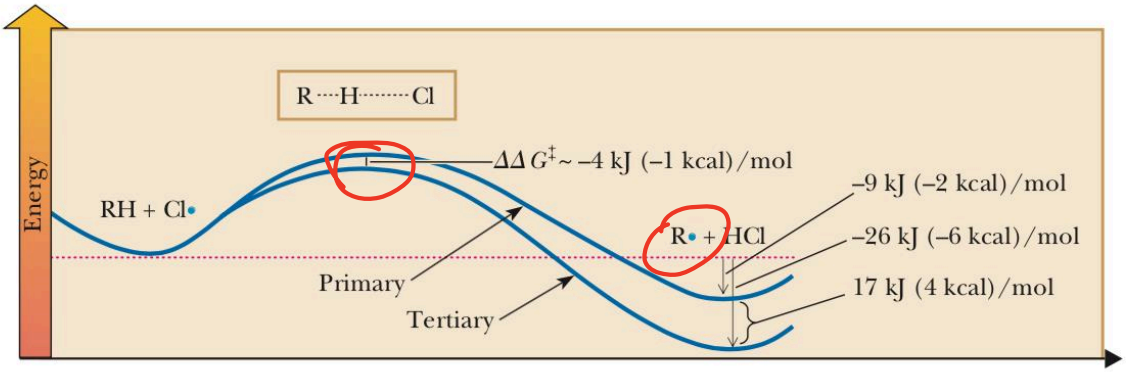
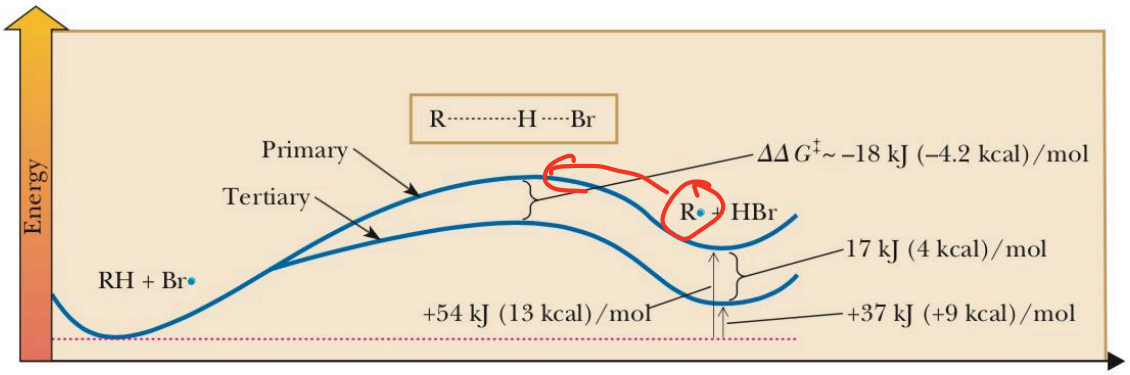


Figure 8.2
Hammond's postulate. Energy diagrams for two one-step reactions. In the exothermic reaction, the transition state occurs early, and its structure resembles that of the reactants. In the endothermic reaction, the transition state occurs late, and its structure resembles that of the products.



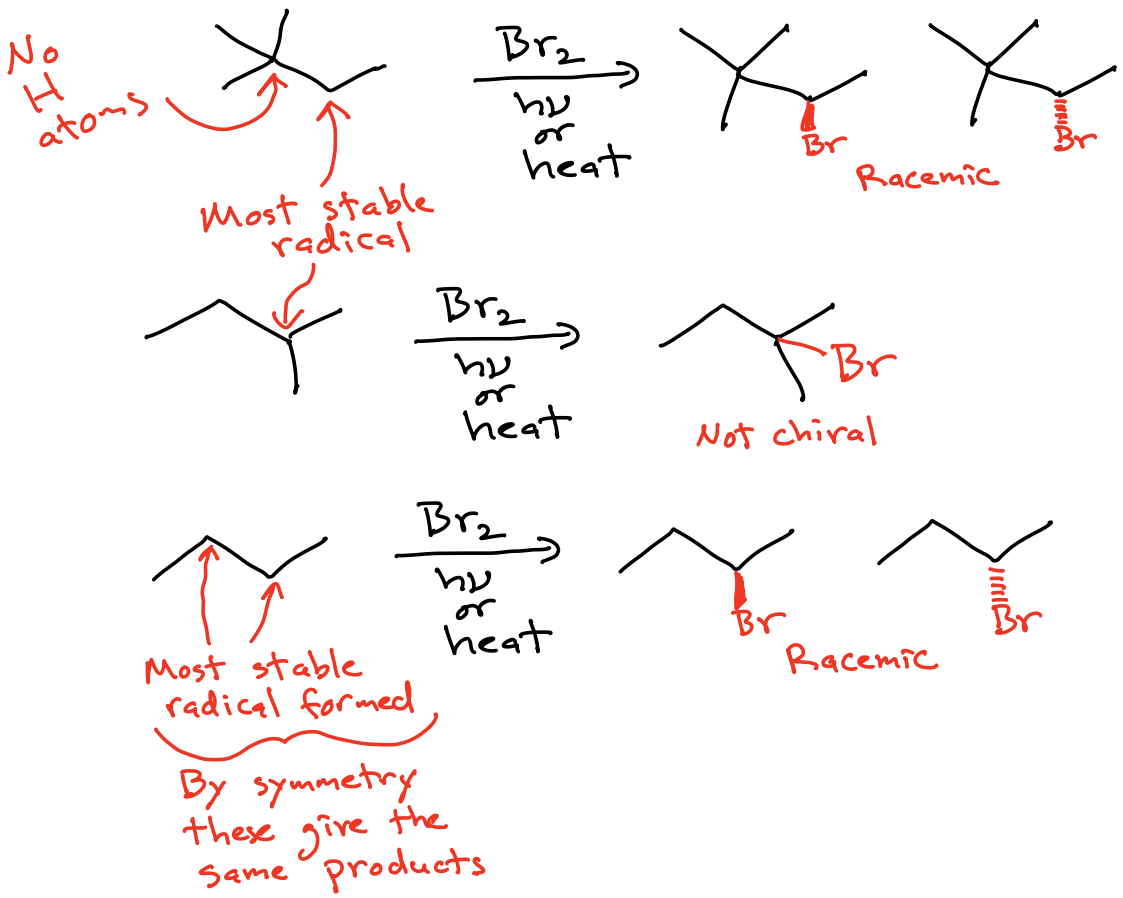
(a) Chlorination



(b) Bromination

Figure 8.3
Transition states and energetics for hydrogen abstraction in the radical chlorination and bromination of 2-methylpropane (isobutane). The product is the intermediate radical, R·.

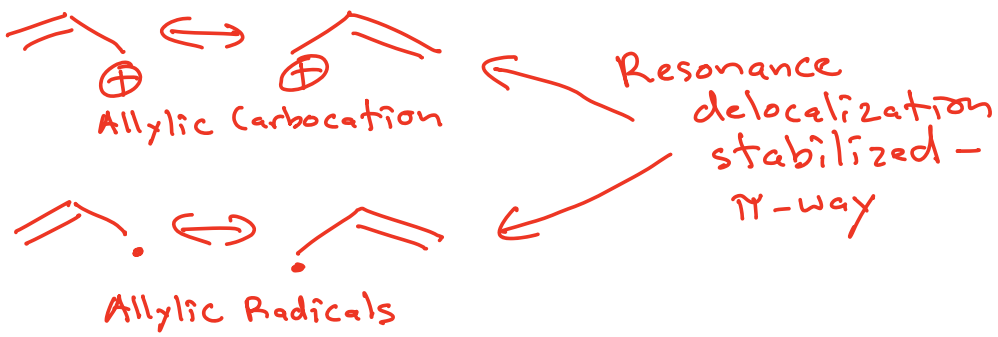
Examples


No H atoms
Most stable radical
Br_2
hν or heat
Br
Racemic
Br
Br_2
hν or heat
Br
Not chiral
Br_2
hν or heat
Br
Racemic
Br
Most stable radical formed
By symmetry these give the same products

Allylic Halogenation

2 New Ideas

A)

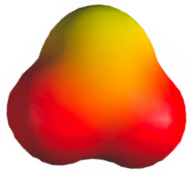


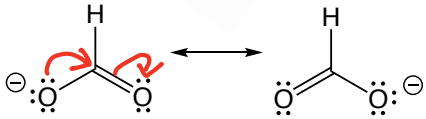
⟹ Radicals easily form on the carbons adjacent to a pi bond (C=C)

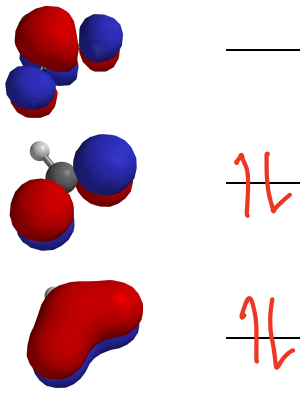
B) When given a choice in allylic halogenation reactions you always make the most stable alkene product

How to think about allyl radicals and allyl cations

Carboxylate anion





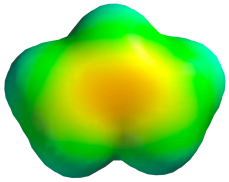


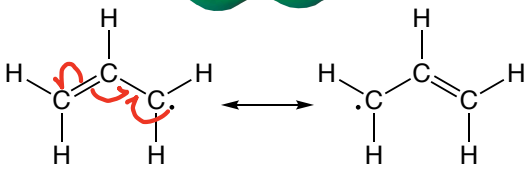
Total # of electrons in the π bond = 2

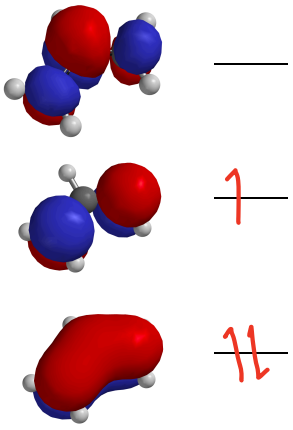
Total # of electrons in the 2p orbital of the other O atom = 2

Total # of electrons in the π-way = 4

Allyl radical





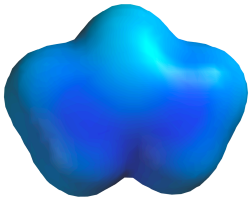


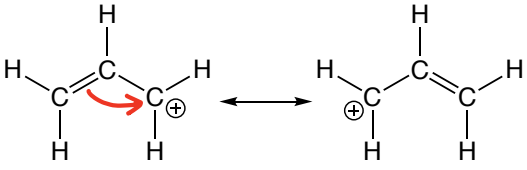
Total # of electrons in the π bond = 2

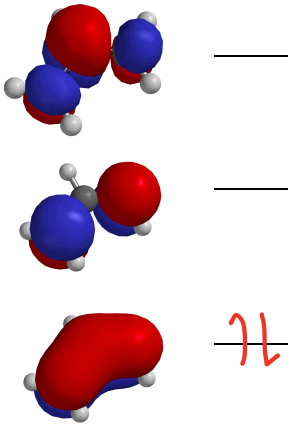
Total # of electrons in the 2p orbital of the other C atom = 1

Total # of electrons in the π-way = 3

Allyl cation







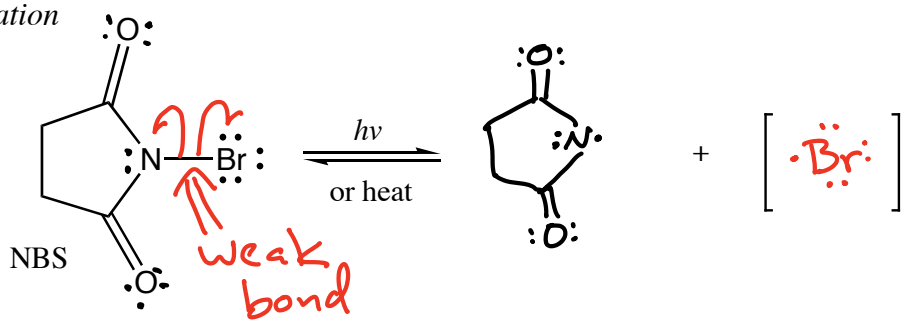
Total # of electrons in the π bond = 2

Total # of electrons in the 2p orbital of the other C atom = 0

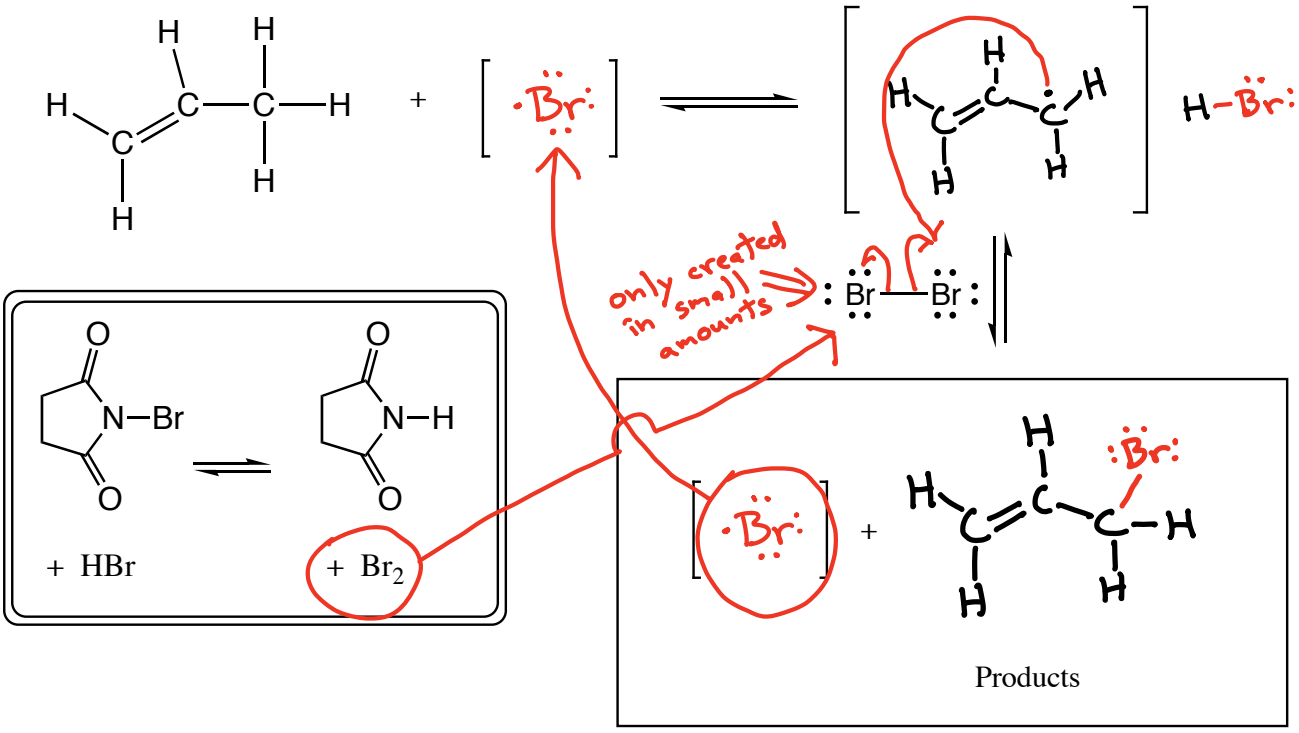
Total # of electrons in the π-way = 2

Allylic Halogenation

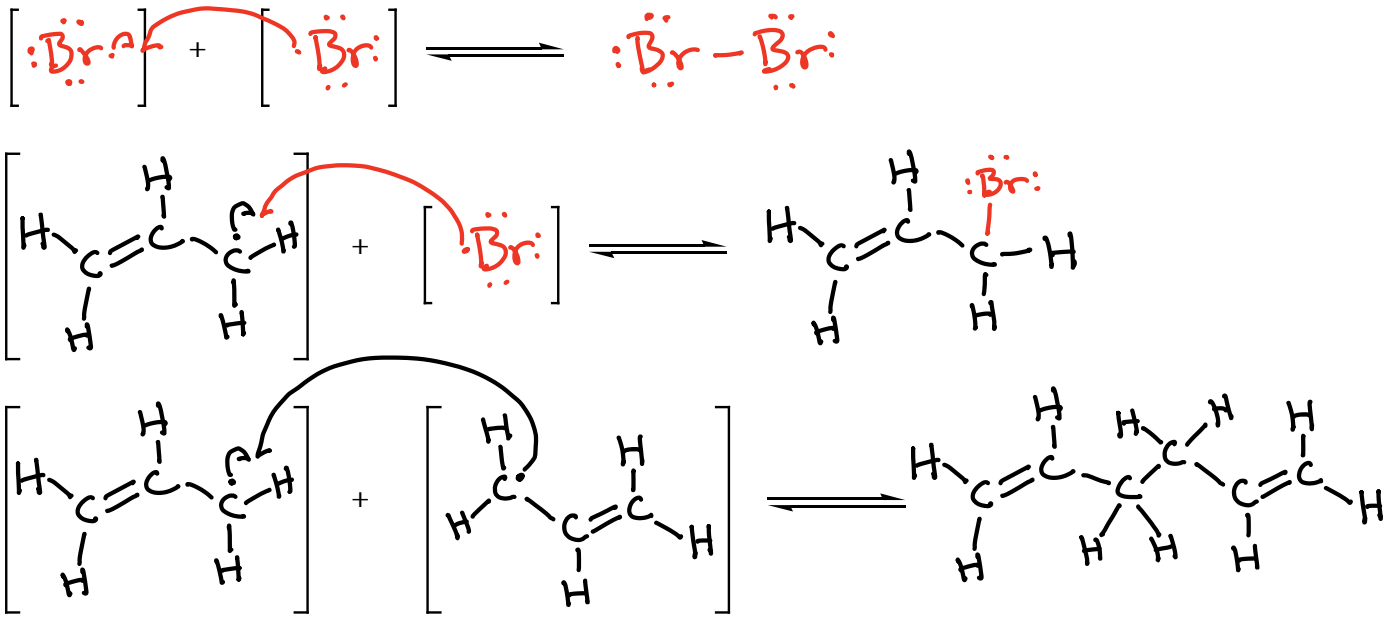
Initiation



Propagation



Termination





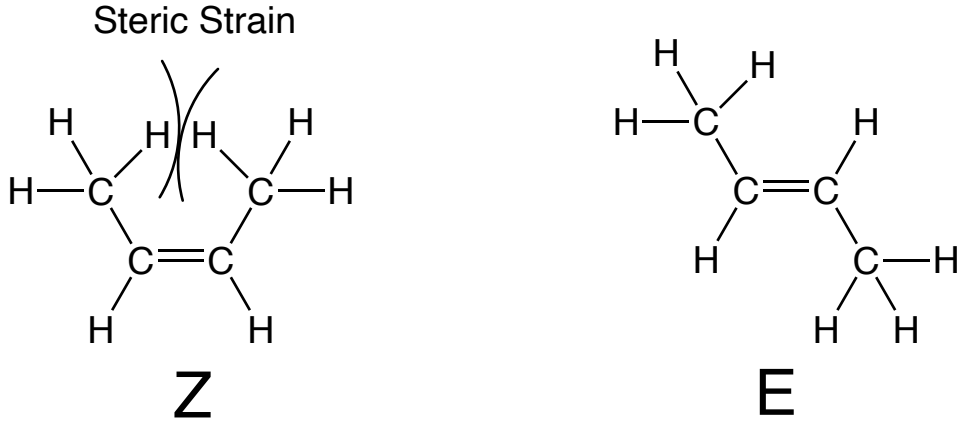
Big Change — For this reaction you need to choose the most stable product, NOT worrying about the most stable contributing structure of an allylic radical intermediate.



From Week 6

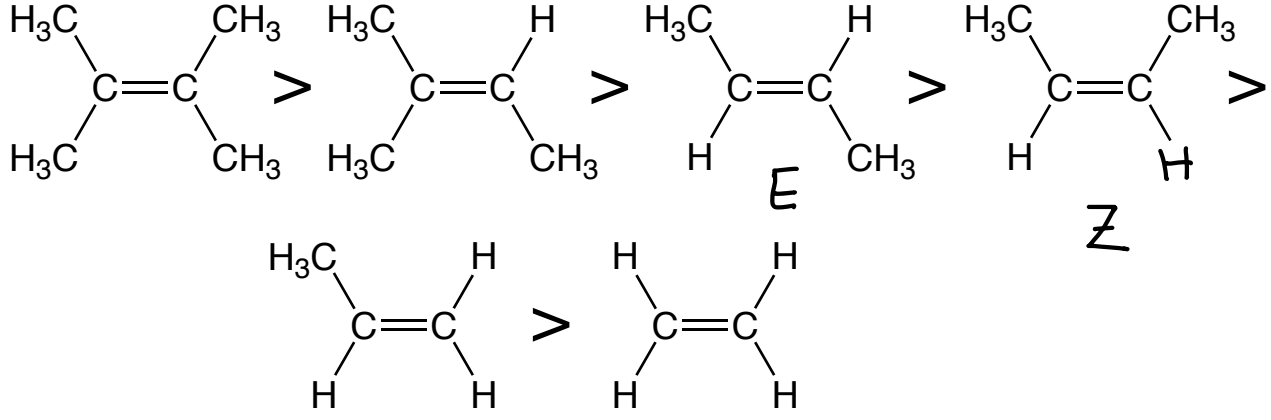
Special Alkene Bonus: Important material you will need to know!

Alkene stability part 1: Z (cis) groups larger than H atoms will crunch into each other causing steric strain.



Alkene stability part 2: For reasons we are not able to tell you, more substituted alkenes have more stable (stronger) pi bonds than alkenes with more H atoms on their sp^2-hybridized C atoms (despite there being steric strain present in the most substituted alkenes).

Strongest Pi Bond



Weakest Pi Bond



Time Capsule: Zaitsev's rule follows this trend!!