Order These Compounds In Order Of Decreasing Carbon-carbon Bond Length.a. H_2CCH_2 < H_3CCH_3 <

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Understanding the order of decreasing carbon-carbon (C–C) bond lengths among different organic compounds is essential in organic chemistry. The bond length influences the molecule’s reactivity, stability, and physical properties. Specifically, when comparing compounds like ethene ($H_2C{=}CH_2$), ethane ($H_3C–CH_3$), and other similar compounds, the key factors determining bond length include the type of bonding (single, double, or triple bonds), hybridization of the involved carbon atoms, and the influence of substituents or conjugation effects.

In this article, we will explore the order of decreasing C–C bond length among various compounds, focusing on $H_2C{=}CH_2$ (ethene) and $H_3C–CH_3$ (ethane), as well as related molecules. We will analyze the factors affecting bond length, explain why certain bonds are longer or shorter, and clarify how hybridization and pi-bonding contribute to these differences.

Fundamental Concepts of Carbon-Carbon Bond Lengths

Before delving into specific compounds, it is crucial to understand the underlying principles governing bond lengths:

1. Bond Types and Their Typical Lengths

- Single bonds (sigma bonds): Generally longer due to a single sigma bond formed by the overlap of sp^3, sp^2, or sp hybrid orbitals.
- Double bonds (sigma + pi): Shorter than single bonds because of the additional pi-bond.
- Triple bonds (sigma + 2 pi): Shortest among C–C bonds due to two pi bonds.

2. Hybridization and Its Effect on Bond Length

- sp hybridized carbons: Have the shortest bonds (~1.20 Å) due to greater s-character (50%), leading to stronger orbital overlap.
- sp^2 hybridized carbons: Bond lengths around 1.34 Å.
- sp^3 hybridized carbons: Longer bonds (~1.54 Å).

3. Influence of Conjugation and Substituents

- Conjugation can lead to bond length alterations through delocalization.
- Electron-donating or withdrawing groups can slightly influence bond lengths.

Comparing the Bond Lengths of Ethene and Ethane

Let's examine the specific compounds mentioned: ethene ($H_2C{=}CH_2$) and ethane ($H_3C–CH_3$).

1. Ethene ($H_2C{=}CH_2$)

- Bond type: Double bond (C= C)
- Hybridization: Both carbons are sp^2 hybridized.
- Typical C–C bond length: Approximately 1.34 Å.
- Bond characteristics: The doubly bonded carbons form a strong sigma bond with a pi bond contributing to bond strength and shorter length.

2. Ethane ($H_3C–CH_3$)

- Bond type: Single bond (C– C)
- Hybridization: Both carbons are sp^3 hybridized.
- Typical C–C bond length: Approximately 1.54 Å.
- Bond characteristics: The single sigma bond is longer due to less effective orbital overlap compared to pi bonds.

3. Comparing Bond Lengths

Given the bond types:
- Double bonds (ethene) are shorter (~1.34 Å),
- Single bonds (ethane) are longer (~1.54 Å),

Therefore, the order of decreasing C–C bond length is:

1. $H_3C–CH_3$ (ethane): approximately 1.54 Å
2. $H_2C{=}CH_2$ (ethene): approximately 1.34 Å

Expressed as:

$H_2C{=}CH_2 < H_3C–CH_3$

or, in the context of the initial question:

Order These Compounds In Order Of Decreasing Carbon-carbon Bond Length. a. $H_2C{=}CH_2$ < $H_3C{-}CH_3$ <

Extending the Comparison to Other Similar Compounds

To deepen our understanding, consider other related compounds and their C–C bond lengths:

1. Propene ($CH_3{-}CH{=}CH_2$)

- Bond types: The bond between the second and third carbons is a double bond (~1.34 Å), while the other bonds are single (~1.54 Å).
- Implication: The double bond length is shorter than single bonds.

2. Butane ($CH_3{-}CH_2{-}CH_2{-}CH_3$)

- Bond types: All single bonds.
- Bond length: Approximately 1.54 Å.

3. Acetylene (C_2H_2)

- Bond type: Triple bond (~1.20 Å).
- Implication: Significantly shorter than double and single bonds.

Summary of typical C–C bond lengths:

- Triple bonds: ~1.20 Å
- Double bonds: ~1.34 Å
- Single bonds: ~1.54 Å

This trend highlights that the more pi bonds involved, the shorter and stronger the bond.

Factors Affecting Carbon-Carbon Bond Lengths

Understanding what influences bond lengths helps in predicting and rationalizing molecular structures.

1. Hybridization

- The hybridization of the carbon atoms determines the orbital overlap.
- sp hybridized carbons: Shortest bonds (~1.20 Å) because of 50% s-character.
- sp^2 hybridized carbons: Intermediate (~1.34 Å).
- sp^3 hybridized carbons: Longest (~1.54 Å).

2. Pi Bonding

- Pi bonds are formed by the sideways overlap of p orbitals.
- Additional pi bonds (double or triple bonds) reduce bond length due to increased orbital overlap.

3. Electron Delocalization and Resonance

- Conjugation can lead to partial double bond character in single bonds, slightly shortening them.

4. Substituents and Steric Effects

- Electron-withdrawing groups can influence electron density, subtly affecting bond lengths.
- Steric hindrance can cause slight elongation or compression of bonds.

Practical Applications and Significance

Understanding the order of bond lengths is not purely academic; it has practical implications:

1. Structural Determination

- Techniques like X-ray crystallography measure bond lengths directly.
- Knowledge of typical bond lengths helps validate experimental data.

2. Reactivity Predictions

- Shorter bonds (like double or triple bonds) are generally more reactive in addition or substitution reactions.
- Longer single bonds tend to be more flexible, influencing reaction pathways.

3. Material Properties

- The strength and length of bonds influence the physical properties of polymers and organic materials.

4. Design of Organic Molecules

- Chemists leverage bond length knowledge to engineer molecules with desired reactivity and stability.

Summary and Key Takeaways

To summarize, the order of decreasing carbon-carbon bond length among the compounds discussed is primarily determined by the type of bond and hybridization:

1. $H_3C–CH_3$ (ethane): ~1.54 Å (single bond, sp^3 hybridized)
2. $H_2C=CH_2$ (ethene): ~1.34 Å (double bond, sp^2 hybridized)
3. Acetylene (C_2H_2): ~1.20 Å (triple bond, sp hybridized)

In the specific context of the initial question, since only ethene and ethane are mentioned, the order is straightforward:

$H_2C=CH_2 < H_3C–CH_3$

This ordering reflects the fundamental principles of hybridization and Pi bonding, emphasizing how the nature of the bond directly impacts its length.

Conclusion

Understanding the order of carbon-carbon bond lengths is fundamental in organic chemistry, influencing how molecules behave and react. The key factors—bond type, hybridization, and conjugation—dictate the bond length hierarchy. Recognizing these trends allows chemists to predict molecular structures, interpret experimental data, and design new compounds with tailored properties.

By mastering these concepts, students and practitioners can deepen their comprehension of molecular geometry and reactivity, essential skills in organic synthesis, materials science, and chemical engineering.

Remember: The shorter the bond, the stronger and more stable it generally is, but also potentially more reactive depending on the context. The balance of these factors underpins much of organic chemistry's predictive power.

Frequently Asked Questions

Which compound has the longest carbon-carbon bond length: $H_2C=CH_2$ or $H_3C–CH_3$?

$H_2C=CH_2$ (ethylene) has a longer carbon-carbon bond length than $H_3C–CH_3$ (ethane) because it contains a double bond, which is shorter than a single bond.

Why does the presence of a double bond affect the carbon-carbon bond length?

Double bonds involve π-bonding which results in shorter and stronger bonds compared to single bonds due to increased electron overlap.

Order the compounds $H_2C=CH_2$ and $H_3C–CH_3$ in decreasing carbon-carbon bond length.

$H_3C–CH_3$ (ethane) has a longer C–C bond length than $H_2C=CH_2$ (ethylene).

What is the typical carbon-carbon bond length in a single bond versus a double bond?

A typical single C–C bond length is about 154 pm, while a double C=C bond is about 134 pm.

Does the type of hybridization affect the carbon-carbon bond length?

Yes; sp^3 hybridized carbons (single bonds) have longer bonds than sp^2 hybridized carbons (double bonds).

How does bond order influence bond length in organic compounds?

Higher bond order (double or triple bonds) results in shorter bond lengths compared to single bonds.

Considering the compounds $H_2C{=}CH_2$ and $H_3C–CH_3$, which has a shorter C–C bond?

$H_2C{=}CH_2$ (ethylene) has a shorter C–C bond than $H_3C–CH_3$ because it has a double bond.

What role does resonance play in bond length variation?

Resonance can delocalize electrons and influence bond lengths, often leading to bond length averages in conjugated systems, but in simple compounds like these, the type of bonding (single vs double) dominates.

Can the bond length differences be observed experimentally, and how?

Yes, bond lengths can be measured using techniques like X-ray crystallography or spectroscopy methods such as infrared or NMR to observe differences between single and double bonds.

Based on bond types, order the compounds from longest to shortest C–C bonds.

$H_3C–CH_3$ (ethane) > $H_2C{=}CH_2$ (ethylene).

Additional Resources

Order These Compounds In Order Of Decreasing Carbon-Carbon Bond Length: $H_2C{=}CH_2$ < $H_3C–CH_3$ <

Understanding the nuances of bond lengths in organic molecules is fundamental to grasping their chemical behavior, stability, and reactivity. In particular, the comparison of carbon-carbon (C–C) bond lengths across different hydrocarbons provides insight into how bonding environments influence molecular structure. When asked to order compounds such as ethene ($H_2C{=}CH_2$) and ethane ($H_3C–CH_3$) in terms of decreasing C–C bond length, it’s essential to analyze the nature of their bonds, the hybridization of the involved carbons, and the influence of conjugation and bond order. This article explores these concepts in detail, examining the factors that determine bond length and applying them to these specific compounds.

Fundamentals of Carbon-Carbon Bond Lengths

Before delving into the specific compounds, it is crucial to understand what determines the length of a C–C bond. Bond length is the distance between the nuclei of two bonded atoms and is influenced primarily by:

- Bond order: Single, double, or triple bonds have different bond lengths due to the number of shared electron pairs.
- Hybridization of the carbon atoms: The s and p orbital character in the hybrid orbitals affects the bond length.
- Resonance and conjugation: Delocalization of electrons can alter electron density distribution, affecting bond length.
- Steric and electronic effects: Substituents and electronic environment can slightly modify bond lengths.

Typically, the order of C–C bond lengths from shortest to longest is:

Triple bond < Double bond < Single bond

Within single bonds, factors like hybridization can cause slight variations, with bonds involving sp^2 hybridized carbons being shorter than those involving sp^3 hybridized carbons.

Analyzing Ethene ($H_2C=CH_2$)

Structure and Bonding

Ethene is a simple alkene characterized by a carbon-carbon double bond. Each carbon atom is sp^2 hybridized, forming a sigma bond with the other carbon and two sigma bonds with hydrogen atoms. The double bond consists of:

- One sigma (σ) bond
- One pi (π) bond

Bond Length Characteristics

The C=C double bond in ethene has a typical length of approximately 1.34 Å. This shorter bond length compared to a C–C single bond results from the increased bond order (double bond).

Features of the C=C bond in ethene:
- Higher bond order: Double bonds are shorter than single bonds due to increased electron sharing.
- Hybridization effect: sp^2 hybridization leads to a higher s-character (33%) in the bonding

orbitals, pulling the nuclei closer together, thereby shortening the bond.

Pros of the Double Bond:
- Greater electron density between carbons enhances reactivity in addition reactions.
- Conjugation possibilities with other π systems.

Cons:
- Less stable than single bonds; more reactive.
- Limited rotational freedom around the double bond.

Analyzing Ethane ($H_3C–CH_3$)

Structure and Bonding

Ethane is a saturated hydrocarbon with a single bond between two sp^3 hybridized carbons. Each carbon forms sigma bonds with three hydrogens and the other carbon atom.

Bond Length Characteristics

The typical C–C single bond length in ethane is approximately 1.54 Å. This length is characteristic of C–C bonds between sp^3 hybridized carbons.

Features of the C–C single bond in ethane:
- Bond order: 1
- Hybridization effect: sp^3 hybridization (25% s-character) results in a slightly longer bond compared to bonds involving sp^2 hybridization.

Pros of the Single Bond:
- High stability and low reactivity.
- Free rotation around the bond axis, providing conformational flexibility.

Cons:
- Less reactive in addition reactions compared to double bonds.
- Lower electron density concentration between carbons.

Order of C–C Bond Lengths in These Compounds

Based on the above analysis, the approximate bond lengths are:

- Ethene ($H_2C=CH_2$): 1.34 Å
- Ethane ($H_3C–CH_3$): 1.54 Å

Given these values, the compounds can be ordered in decreasing carbon-carbon bond length as:

$H_3C–CH_3$ (ethane) > $H_2C=CH_2$ (ethene)

Additional Factors Influencing Bond Lengths and Considerations

Resonance and Conjugation Effects

In compounds where conjugation occurs, electron delocalization can affect bond lengths. For example, in conjugated dienes, the C=C bonds can have slightly different lengths due to resonance stabilization. However, in ethene and ethane, conjugation effects are minimal or absent.

Impact of Substituents

Substituents attached to the carbons can influence bond lengths through inductive or hyperconjugative effects, but these are not relevant in the simple molecules under discussion.

Comparison with Other Hydrocarbons

- Propene ($H_2C=CH–CH_3$): The C=C bond length remains similar (~1.34 Å), but the single bonds may vary slightly.
- Alkyne (H–C≡C–H): The C≡C triple bond (~1.20 Å) is shorter than double and single bonds.

Implications of Bond Length Variations in Chemical Reactivity

Understanding bond length variations helps predict reactivity:

- Shorter bonds (double/triple) are generally more reactive in addition or substitution reactions.
- Longer bonds (single) tend to be more stable but less reactive.
- The hybridization state influences not only bond length but also the distribution of electron density, affecting reaction mechanisms.

Conclusion

Summarizing the analysis, the order of compounds based on decreasing carbon-carbon bond length is:

$H_3C–CH_3$ (ethane) > $H_2C=CH_2$ (ethene)

This ordering aligns with the fundamental principles of bond order and hybridization. Ethane's single bonds are longer due to their lower bond order and sp^3 hybridization, whereas ethene's double bonds are shorter because of the increased bond order and sp^2 hybridization. Recognizing these structural differences is essential in organic chemistry, influencing both the physical properties and reactivity profiles of hydrocarbons.

Final note: While the initial question focused on just these two compounds, this analysis underscores the broader principles governing bond lengths, which can be extended to more complex molecules and bonding scenarios.

Order These Compounds In Order Of Decreasing Carbon Carbon Bond Length A H 2cch 2 Lt H 3cch 3 Lt

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