Place The Following Substances In Order Of Decreasing Boiling Point. CH 3 CH 2 OH F2 CO 2 O CO2>F2>

Understanding the Order of Substances Based on Boiling Points

Place The Following Substances In Order Of Decreasing Boiling Point. CH_3CH_2OH, F_2, CO_2, O, CO_2 > F_2 > is a common question in chemistry that tests your understanding of intermolecular forces, molecular structure, and how they influence boiling points. The boiling point of a substance is the temperature at which its vapor pressure equals the external atmospheric pressure, allowing it to transition from liquid to gas. Several factors influence boiling points, including molecular weight, types of intermolecular forces, molecular shape, and polarity. In this article, we will explore each of these factors and systematically analyze the given substances to determine their order of decreasing boiling points.

Fundamentals of Boiling Points and Intermolecular Forces

What Determines the Boiling Point?

The boiling point of a substance depends primarily on the strength of the intermolecular forces (IMFs) present. The stronger these forces, the more energy (heat) is required to overcome them, leading to a higher boiling point. The main types of IMFs include:

- **London Dispersion Forces (Van der Waals forces):** Present in all molecules, especially significant in nonpolar molecules.
- **Dipole-Dipole Interactions:** Occur in polar molecules where partial positive and negative charges attract each other.
- **Hydrogen Bonding:** A special, strong type of dipole-dipole interaction occurring when hydrogen is bonded to highly electronegative atoms like oxygen, nitrogen, or fluorine.

Effect of Molecular Weight and Structure

Generally, larger molecules with higher molecular weights have greater London dispersion forces, leading to higher boiling points. Additionally, the molecular shape and symmetry can influence how effectively molecules pack and interact, affecting boiling points.

Analyzing the Given Substances

Substance 1: Ethanol (CH_3CH_2OH)

Ethanol is an alcohol with the molecular formula CH_3CH_2OH. It exhibits several key features:

- **Polarity:** Ethanol is polar due to the hydroxyl group (-OH).
- **Hydrogen Bonding:** It can form hydrogen bonds, which significantly increase its boiling point.
- **Molecular Weight:** Approximately 46 g/mol.

Because of hydrogen bonding, ethanol has a relatively high boiling point for a molecule of its size, around 78.37°C.

Substance 2: Fluorine (F_2)

Fluorine is a diatomic molecule composed of two fluorine atoms:

- **Polarity:** F_2 is nonpolar.
- **Intermolecular Forces:** Dominated by London dispersion forces.
- **Molecular Weight:** About 38 g/mol.

Because F_2 is nonpolar and has a relatively low molecular weight, its boiling point is quite low, approximately -188°C.

Substance 3: Carbon Dioxide (CO_2)

Carbon dioxide is a linear, nonpolar molecule with the formula CO_2. Key characteristics include:

- **Polarity:** Nonpolar overall due to its linear symmetric shape.
- **Intermolecular Forces:** Primarily London dispersion forces.
- **Molecular Weight:** About 44 g/mol.

CO_2 sublimates at about -78.5°C under atmospheric pressure, meaning it transitions directly from solid to gas. Its boiling point as a liquid is around -56.6°C under high pressure.

Substance 4: Oxygen (O)

Atomic oxygen (O) is a monoatomic element. However, in most contexts, "O" refers to atomic oxygen, which is a reactive species. For the purposes of boiling points, it is not a typical molecular substance. If the question refers to molecular oxygen (O_2), then:

- **Polarity:** Nonpolar diatomic molecule.
- **Intermolecular Forces:** London dispersion forces.
- **Molecular Weight:** About 32 g/mol.

O_2 has a boiling point of approximately -183°C.

Order of Substances Based on Boiling Points

Step-by-Step Analysis

To determine the order, we compare the strength of intermolecular forces, molecular weights, and known boiling points:

1. **Ethanol (CH_3CH_2OH):** High boiling point (~78°C) due to hydrogen bonding.
2. **CO_2:** Sublimates at -78.5°C, with a boiling point around -56.6°C under pressure, primarily London dispersion forces.
3. **F_2:** Boiling point approximately -188°C, weak London dispersion forces.
4. **O (assuming O_2):** Boiling point about -183°C, similar to F_2 but slightly higher.

Final Order from Highest to Lowest Boiling Point

- **CH_3CH_2OH (Ethanol):** Highest due to hydrogen bonding.
- **CO_2:** Sublimates around -78.5°C, higher than F_2 and O_2.
- **O_2 (Atomic oxygen if considered):** Boiling point around -183°C.

- **F_2:** Boiling point approximately -188°C.

Summary of the Order

Therefore, the substances in order of decreasing boiling point are:

$CH_3CH_2OH > CO_2 > O_2 > F_2$

Implications and Applications

Understanding the order of boiling points is crucial in various chemical processes, such as distillation, where separation of substances depends on differences in boiling points. For instance, in industrial settings, ethanol can be separated from other compounds through distillation owing to its high boiling point relative to many gases.

Practical Tips for Predicting Boiling Points

1. Always consider the type of intermolecular forces: hydrogen bonds > dipole-dipole > London dispersion.

2. Compare molecular weights; heavier molecules tend to have higher boiling points if forces are similar.

3. Look at molecular polarity; polar molecules generally have higher boiling points due to dipole interactions.

4. Remember that molecular shape and symmetry can influence how molecules pack and interact.

Conclusion

In summary, the order of substances based on decreasing boiling point depends on the nature and strength of intermolecular forces, molecular weight, and polarity. Ethanol, with its hydrogen bonding capabilities, has the highest boiling point among the listed substances, followed by carbon dioxide, atomic oxygen (or molecular oxygen), and fluorine. Recognizing these trends helps chemists predict physical properties and design processes accordingly.

FAQs

1. Why does ethanol have a higher boiling point than CO_2?

Ethanol exhibits hydrogen bonding, a particularly strong intermolecular force, which requires more energy to break, resulting in a higher boiling point compared to CO_2, which mainly relies on London dispersion forces.

2. Why are F_2 and O CO > F_2 > CO_2

Additional Considerations and Clarifications

- Hydrogen Bonding Dominance: Ethanol's high boiling point mainly results from hydrogen bonding, which is much stronger than London dispersion or dipole-dipole forces.

- Diatomic Gases: CO and F_2 are both diatomic gases, but the slight difference in boiling points arises from their molar masses and polarity. CO's polarity and dipole-dipole interactions give it a marginally higher boiling point than F_2, despite F_2's larger molar mass, because London dispersion forces increase with molar mass but are weaker than dipole interactions.

- Sublimation of CO_2: CO_2 sublimates at -78.5°C, skipping the liquid phase under standard pressure. Nonetheless, its sublimation point is a good indicator of its weak intermolecular forces.

- Molecular Size and Mass: While larger molar mass generally

leads to higher boiling points, the type of intermolecular forces often dominates the trend, especially in molecules with different bonding characteristics.

Practical Implications

Understanding these boiling points helps in various practical contexts:

- Ethanol's high boiling point makes it suitable for beverages, solvents, and biofuel applications.
- Low boiling points of F_2 and CO imply they require careful handling and storage at low temperatures.
- CO_2’s sublimation point is critical in its use as a refrigerant and in dry ice applications.

Summary

In conclusion, the substances can be ordered in decreasing boiling point as:

Ethanol (78.37°C) > Carbon Monoxide (-191.5°C) > Fluorine (-188°C) > Carbon Dioxide (-78.5°C sublimation point)

This order reflects the interplay of molecular structure,

polarity, and intermolecular forces, with hydrogen bonding playing a pivotal role in ethanol’s elevated boiling point. Recognizing these factors is essential for chemists and engineers alike when designing processes involving these substances.

Final Note: Always consider experimental conditions (pressure, purity, etc.) when dealing with boiling points, as they can influence the observed values.

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