What are Van der Waals forces

Van der Waals forces are weak, short-range attractive forces between atoms and molecules that arise from temporary fluctuations in electron distribution, rather than from formal chemical bonding (like ionic or covalent bonds). They're named after Dutch physicist Johannes Diderik van der Waals.

Where they come from

Even in atoms or molecules with no permanent charge separation, electrons are constantly moving. At any given instant, they might be unevenly distributed, creating a tiny, temporary dipole (a slight positive end and slight negative end). This temporary dipole can induce a similar dipole in a neighboring atom or molecule, and the two then attract each other briefly.

The main types

Van der Waals forces are usually broken down into a few components:

1. **London dispersion forces** – present in *all* atoms and molecules, arising from those instantaneous, fluctuating dipoles. These are the only intermolecular force acting between nonpolar molecules (like noble gases or O_2).
2. **Dipole-dipole forces** – occur between molecules that have permanent dipoles (like HCl), where the positive end of one molecule attracts the negative end of another.
3. **Dipole-induced dipole forces** – a permanent dipole in one molecule induces a temporary dipole in a nearby nonpolar molecule.

(Hydrogen bonding is sometimes considered a special, stronger case related to dipole-dipole interactions, though it's often treated as its own category.)

Key characteristics

- **Weak**: Much weaker than covalent or ionic bonds — typically on the order of a few kJ/mol versus hundreds for covalent bonds.
- **Short-range**: They weaken rapidly with distance (roughly as $1/r^6$), so they only matter when atoms/molecules are very close.
- **Universal**: Every atom and molecule experiences at least the dispersion component, since electron motion is unavoidable.
- **Additive**: Larger molecules with more electrons (like long hydrocarbon chains) have stronger cumulative Van der Waals attractions, even though each individual interaction is weak.

Why they matter

Van der Waals forces explain a surprising range of phenomena:

- Why nonpolar substances like nitrogen or methane can still condense into liquids at low temperatures
- Why larger alkanes (like octane) have higher boiling points than smaller ones (like methane), despite both being nonpolar
- How gecko feet stick to surfaces (their toe hairs use dispersion forces to cling to walls)
- The structure and stability of proteins and DNA, where they contribute alongside hydrogen bonds
- Real-gas behavior deviations from the ideal gas law, which is actually where van der Waals first developed his equation of state

Want me to go deeper into any of these — like the math behind the $1/r^6$ dependence, or how they factor into a specific context like biology or materials science?

Ask Claude your own question