

# Intermolecular Forces

## Chapter 11

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Why my sister never believes me anymore...



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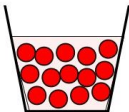
## States of Matter

**SOLIDS**



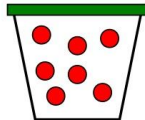
The molecules are held together with strong bonds. They don't move very easily so SOLIDS can keep their own shape and size

**LIQUIDS**



The molecules have weaker bonds. They can move around slightly so LIQUIDS can flow. They can't keep their shape unless they're in a container.

**GASES**



The molecules are free to move around. They can spread around an open space quickly and freely. GASES can't keep their shape unless they are kept in a sealed container.

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## What are INTERmolecular (IMF) forces?

- ▶ Forces of attraction **between** different molecules
- ▶ Vary in strength but are usually weaker than bonds
- ▶ Not the same as chemical bonds (intramolecular force within molecules)

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## Why are IMFs important?

- ▶ Explain reasons for many physical properties of matter
  - ▶ States of matter, boiling/melting points, solubility, etc

Bonding type	Substance	Boiling Point
Non Polar Covalent	CH <sub>4</sub>	-164 °C
Polar Covalent	NH <sub>3</sub>	-33 °C
Ionic	NaCl	1413 °C
Metallic	Fe	2750 °C

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## Why are IMFs important?

- ▶ Example: Boiling Point -
  - ▶ Is there a relationship to bond type?
  - ▶ Is this the only factor?

Bonding type	Substance	Boiling Point
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## Types of IMFs—LDFs

### ▶ London Dispersion Force (or just dispersion force):

- ▶ Weakest of the IMFs when compared on 1:1 basis
- ▶ Form between **all** molecules but are the only IMF that forms between non-polar molecules and noble gases
- ▶ Attraction between *instantaneous/momentary/temporary* dipoles between molecules



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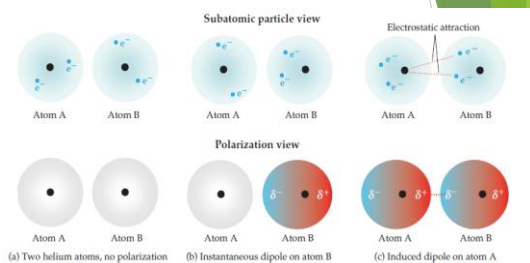
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## Types of IMFs—LDFs



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## Types of IMFs—LDFs

- ▶ Polarizability = degree to which the e- cloud can be distorted to form temporary dipoles
- ▶ More polarizable = stronger dispersion force
- ▶ Polarizability increases as the # of e- in an atom/molecule increases
- ▶ Larger mass of atoms/molecules = larger force
- ▶ Larger shape/surface area also = larger dispersion force

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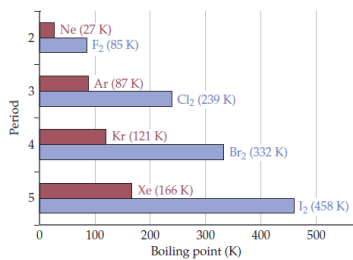
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## Relationship between BP and molecular weight



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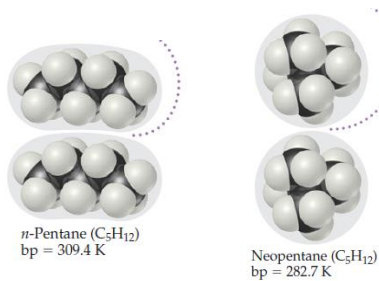
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## Relationship between BP and molecular shape




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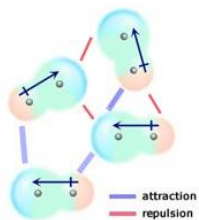
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## Types of IMFs—Dipole-dipole

### ► Dipole-Dipole Force:

- Opposite ends of POLAR molecules attract
- More polar = larger force



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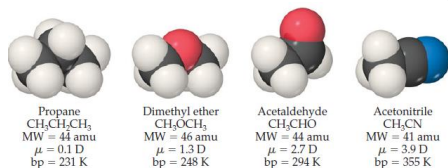
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## Polarity and dipole-dipole force strength



Increasing polarity  
Increasing strength of dipole-dipole forces

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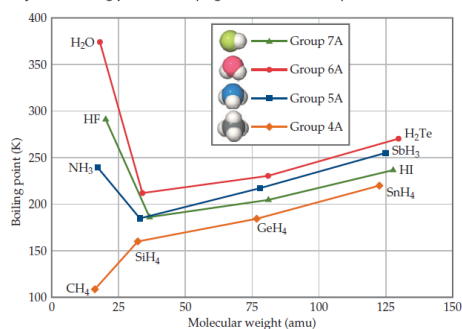
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Why is the boiling point of  $\text{SnH}_4$  higher than that of  $\text{CH}_4$ ?




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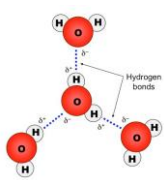
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## Types of IMFs—H-bonds

### ▶ Hydrogen "Bonding":

- ▶ a particularly strong case of the dipole-dipole force
- ▶ forms between a very (+) pole and a very (-) pole of two polar molecules
  - ▶ Due to large difference in electronegativity between bonded atoms
  - ▶ A hydrogen atom directly bound to a highly electronegative N, O, F is attracted to the NOF on another molecule




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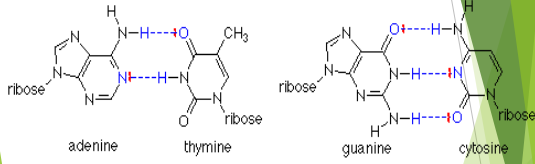
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### Example: H-bonding in DNA



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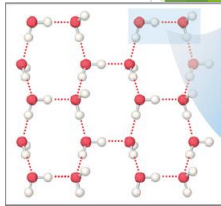
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### Example: H-bonding in H<sub>2</sub>O

- ▶ Water is more dense as a liquid than as a solid (opposite of most substances)
- ▶ LIFE!



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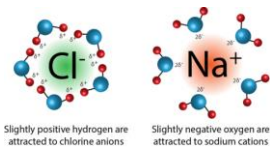
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### Types of IMFs—Ion-dipole

- ▶ **Ion-Dipole Force:**
  - ▶ Form between ions and polar molecules
  - ▶ Cations attracted to (-) pole
  - ▶ Anions attracted to positive (+) pole



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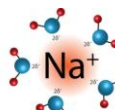
## Types of IMFs—Ion-dipole

### ▶ Ion-Dipole Force:

- ▶ Stronger than dipole-dipole (even H-bonds)
- ▶ Strength of attraction increases with increasing magnitude of:
  - ▶ ionic charge
  - ▶ dipole moment/polarity of molecule



Slightly positive hydrogen are attracted to chlorine anions



Slightly negative oxygen are attracted to sodium cations

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## Types of IMFs

- ▶ **Induced-Dipole Force:** Weak IMF that occurs when an ion or molecule with a dipole causes (induces) a dipole to form in an atom or molecule that does not otherwise have pole

- ▶ Ion-Induced Dipole Force
- ▶ Dipole-Induced Dipole Forces



For neutral atom with no dipole. For anion/cation the location of  $\ominus$  or  $\oplus$  nucleus.



Upon approach of an ion, the electrons in the atom respond and the atom develops a dipole.



Spherical atom with no dipole. The dot indicates the location of the nucleus.



20 Upon approach of a molecule with a dipole, electrons in the atom respond and the atom develops a dipole.

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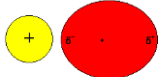
## Types of IMFs

### ▶ Ion-Induced Dipole Force

- ▶ Attraction that results from the approach of an ion that induces a dipole in an atom or non-polar molecule by disturbing the arrangement of electrons in the non-polar species



Spherical atom with no dipole. The dot indicates the location of the nucleus.



Upon approach of a charged ion, electrons in the atom respond and the atom develops a dipole.

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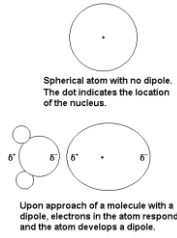
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## Types of IMFs

### ► Dipole-Induced Dipole Forces

► Attraction that results from the approach of a polar molecule that induces a dipole in an atom or non-polar molecule by disturbing the arrangement of electrons in the non-polar species



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## Relative Strength of IMFs

- STRONGEST**
- Ion-dipole
  - Hydrogen bond
  - Dipole-Dipole
  - Ion-Induced Dipole
  - Dipole - Induced Dipole
  - Dispersion Forces
- WEAKEST**




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