N29 – Intermolecular Forces

Going in Depth

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Going in Depth

Target: I can give detailed and complex reasoning for how various IMFs work, and how they affect the properties of various substances.

Types of IMFs

- London Dispersion Forces
- Dipole-Dipole
- Hydrogen Bond

These three talked about in Honors Chem

- Ion-Dipole Forces
- Ion Induced Dipole
- Dipole Induced Dipole

These three talked are probably new

Dipole – Dipole Attractions

Polar molecules have a permanent dipole.

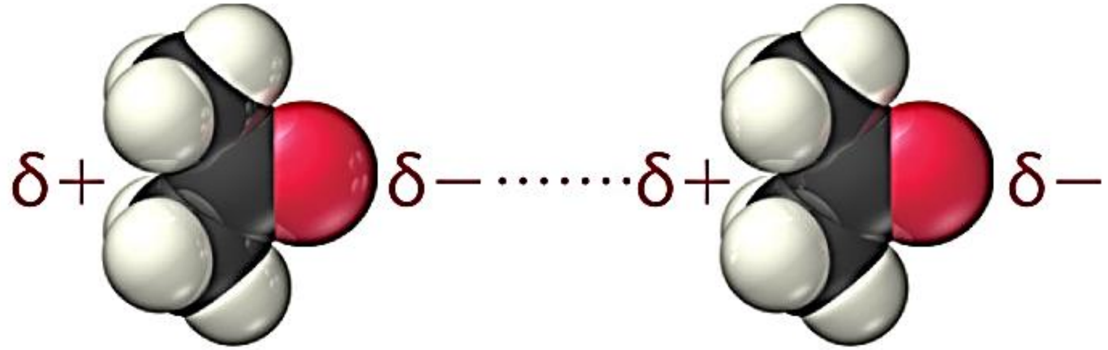
- Bond polarity and shape
- Dipole moment

The permanent dipole...

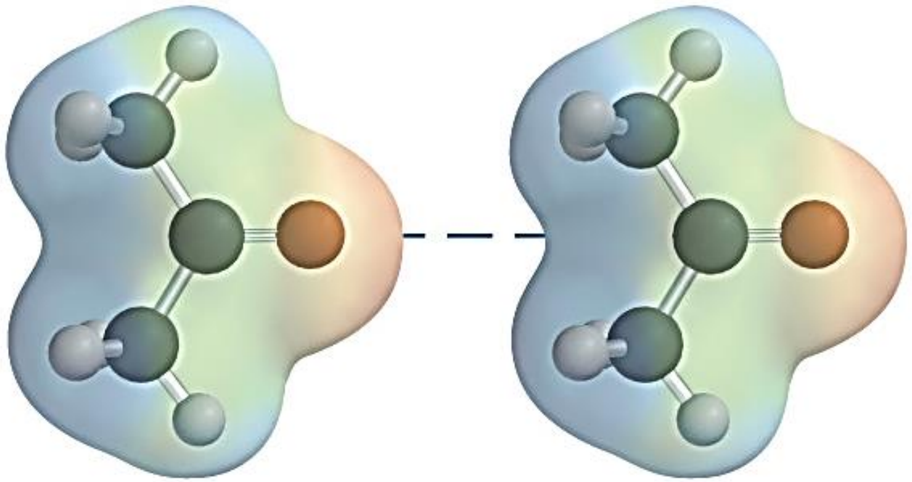
- **adds to attractive forces between the molecules,**
  - **raising the boiling and melting points compared to nonpolar molecules of similar size and shape.**

Dipole – Dipole Attractions

The partial positive end of a polar molecule is attracted to the partial negative end of its neighbor.

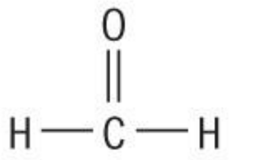
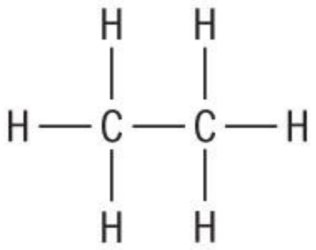


Space-filling model



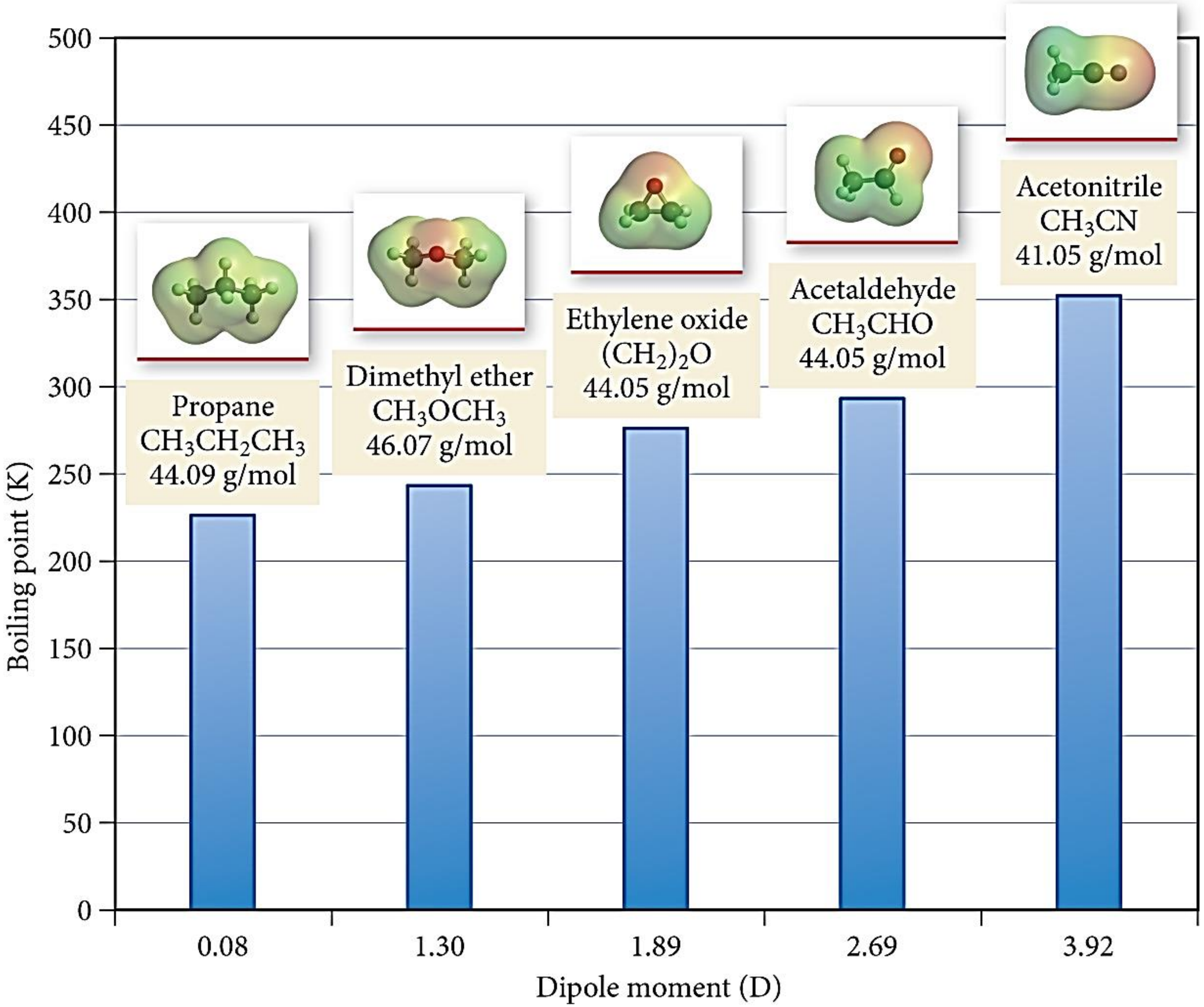
Electrostatic potential map

Effect of DP-DP Attractions on BP and MP

Name	Formula	Molar Mass (amu)	Structure		bp (°C)	mp (°C)
Formaldehyde	CH_2O	30.03			−19.5	−92
Ethane	C_2H_6	30.07			−88	−172

Formaldehyde has DP-DP and higher BP and MP

Dipole Moment and Boiling Point



Hydrogen Bonding

H – NOF:

Way to remember it but don't write it on AP test!

- When a very electronegative atom is bonded to H, **it strongly pulls the bonding electrons toward it.**

  ONLY :N—H :O—H or :F—H

- Because H has no other electrons, when its e- is pulled away, the **nucleus becomes de-shielded, exposing the H proton**.

- **The exposed proton acts as a very strong partial positive charge, attracting e- clouds from neighboring molecules.**

Hydrogen Bonding

Results in higher boiling points and melting points than similar substances that cannot.

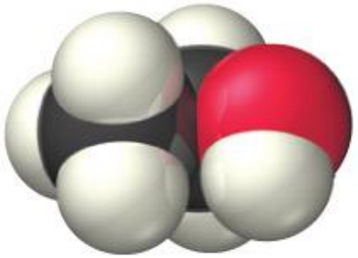
H-bonds are very strong intermolecular attractive forces.

- (Usually) stronger than dipole–dipole or dispersion forces

But H-bonds are not nearly as strong as chemical bonds.

- 2–5% the strength of covalent bonds

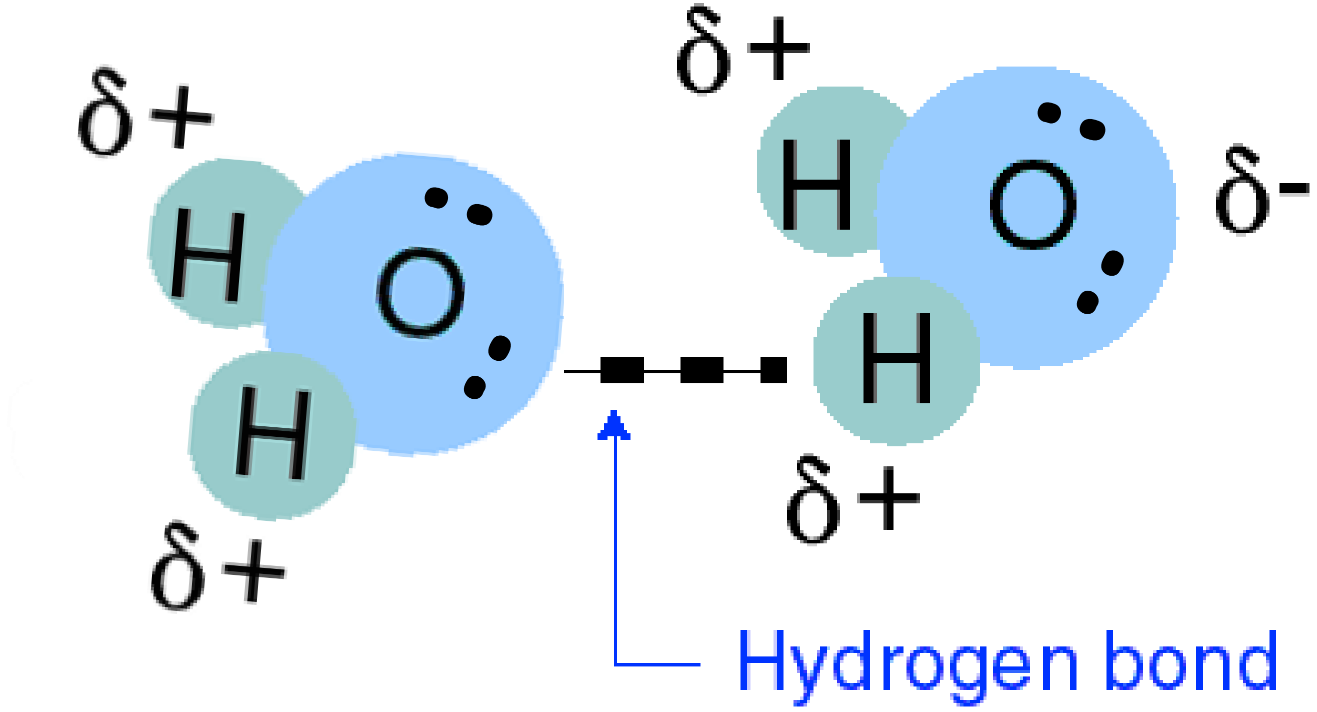
Effect of H-Bonding on BP

Name	Formula		Molar Mass (amu)	Structure	bp (°C)	mp (°C)
Ethanol	C_2H_6O		46.07	CH_3CH_2OH	78.3	−114.1
Dimethyl Ether	C_2H_6O		46.07	CH_3OCH_3	−22.0	−138.5

Ethanol has H-Bonding and higher BP and MP

Hydrogen Bonding

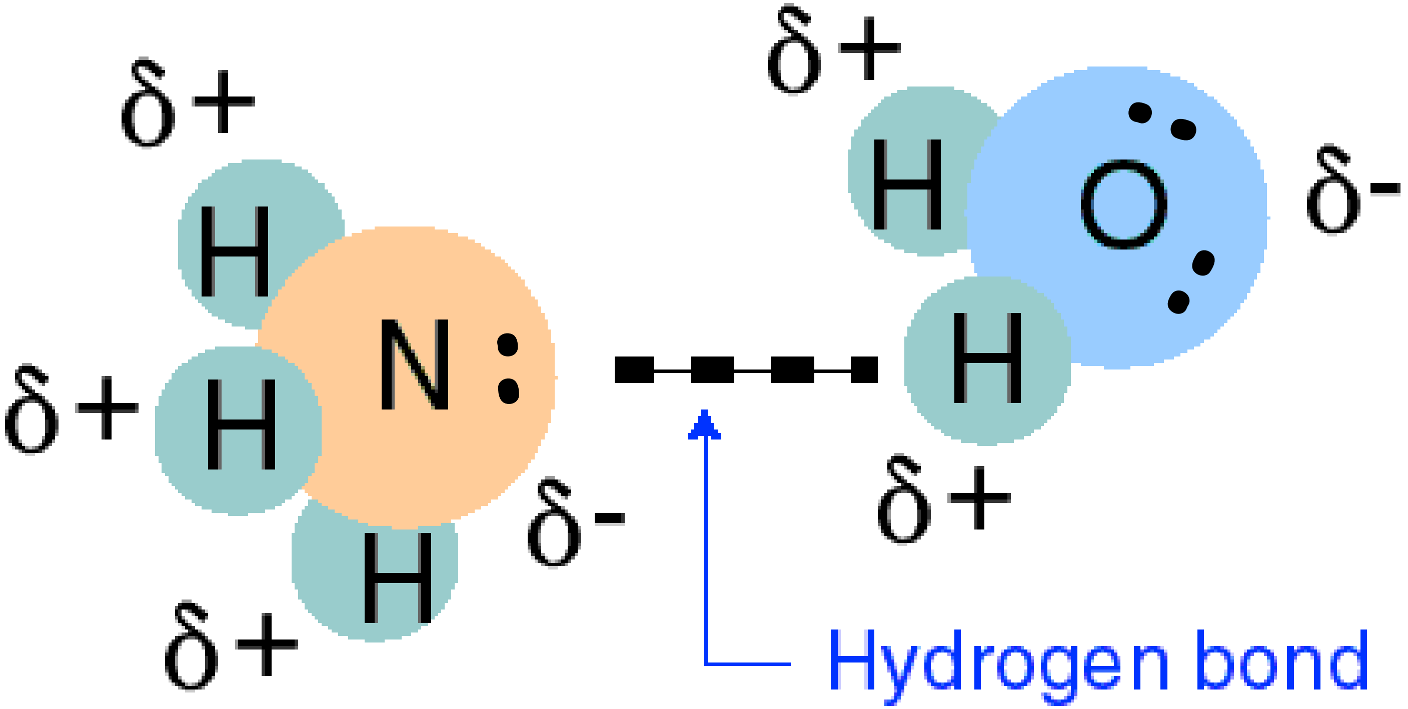
Some substances can hydrogen bond with themselves.



Hydrogen bonding between water and water

Hydrogen Bonding

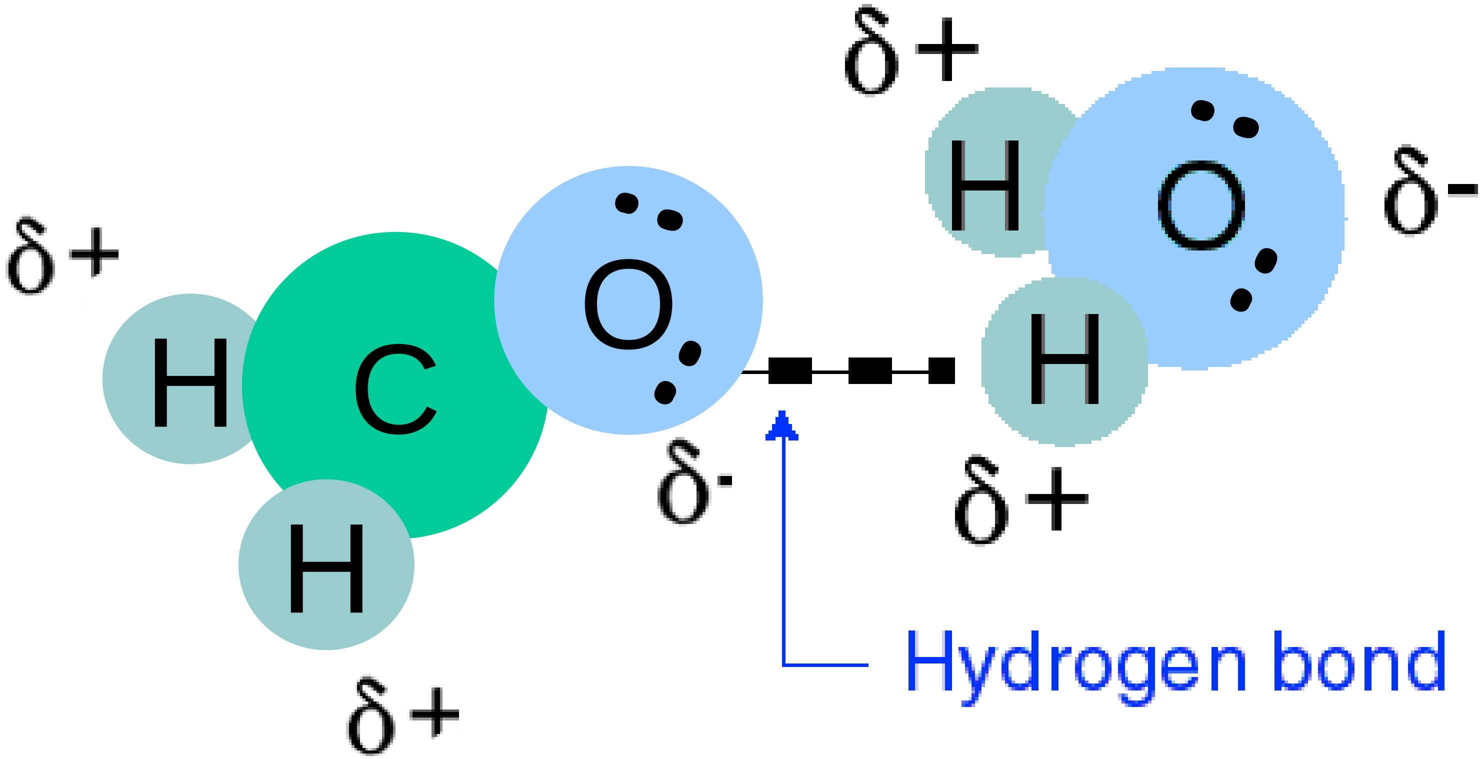
Some substances can also hydrogen bond with other molecules.



Hydrogen bonding between ammonia and water

Hydrogen Bonding

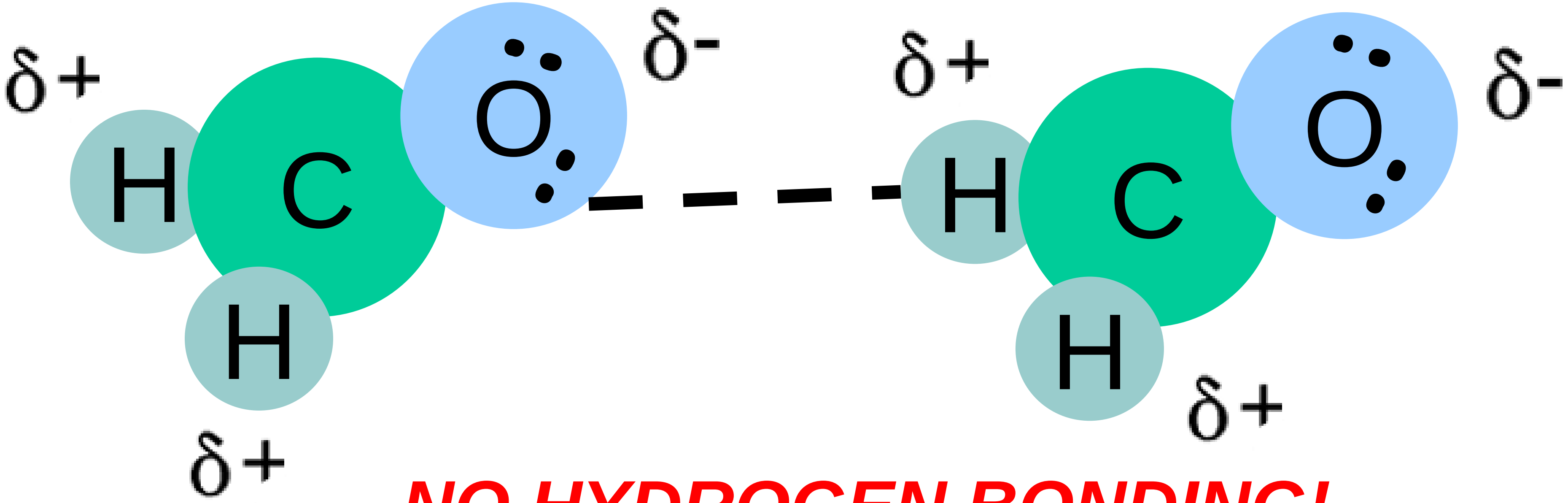
Some substance can hydrogen bond with other molecules, but not with themselves



Hydrogen bonding between formaldehyde and water

(not) Hydrogen Bonding

Some substance can hydrogen bond with other molecules, but NOT with themselves



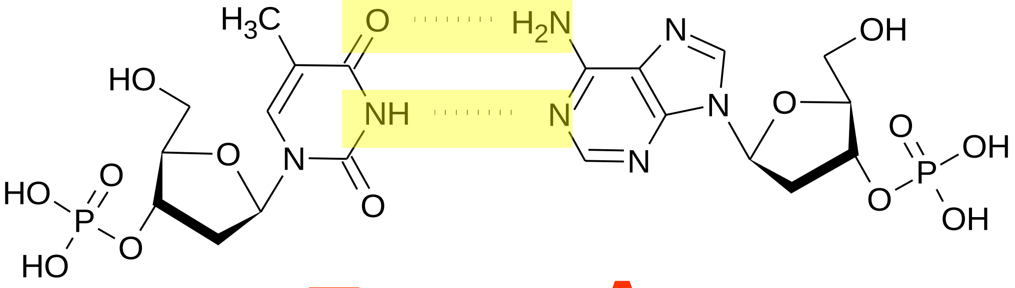
NO HYDROGEN BONDING!

Proton on H is not exposed enough!

Yes Dipole-Dipole. NO hydrogen bond

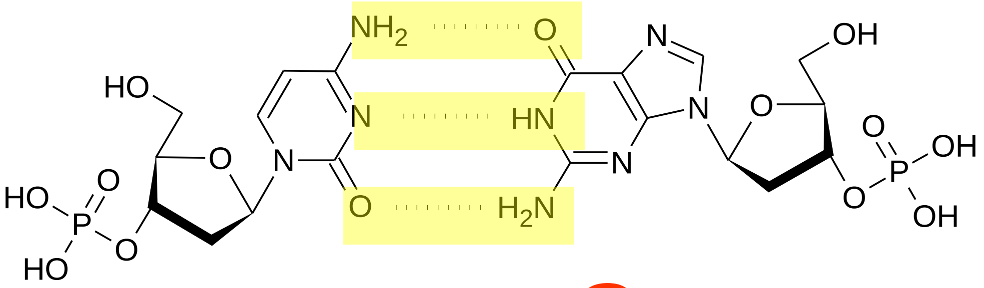
Hydrogen Bonding in DNA and Proteins

Thymine hydrogen bonds to Adenine



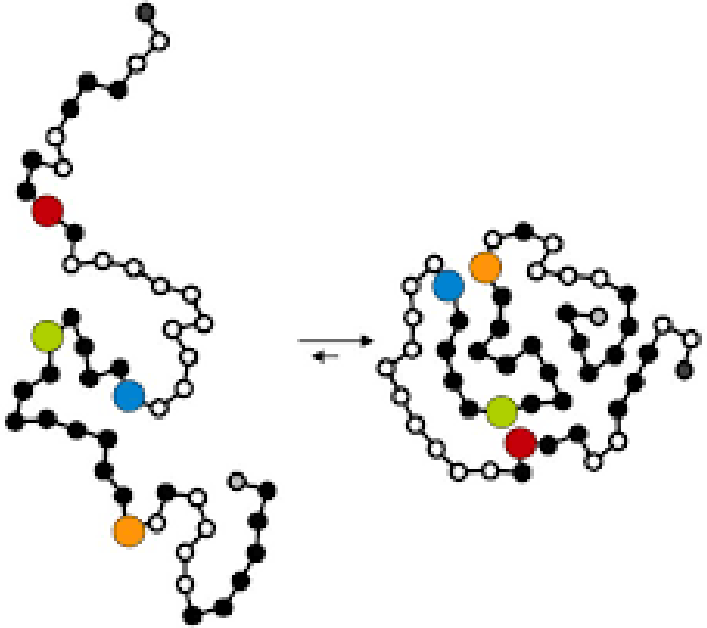
T - - - - A

Cytosine hydrogen bonds to Guanine



C - - - - G

Protein folding



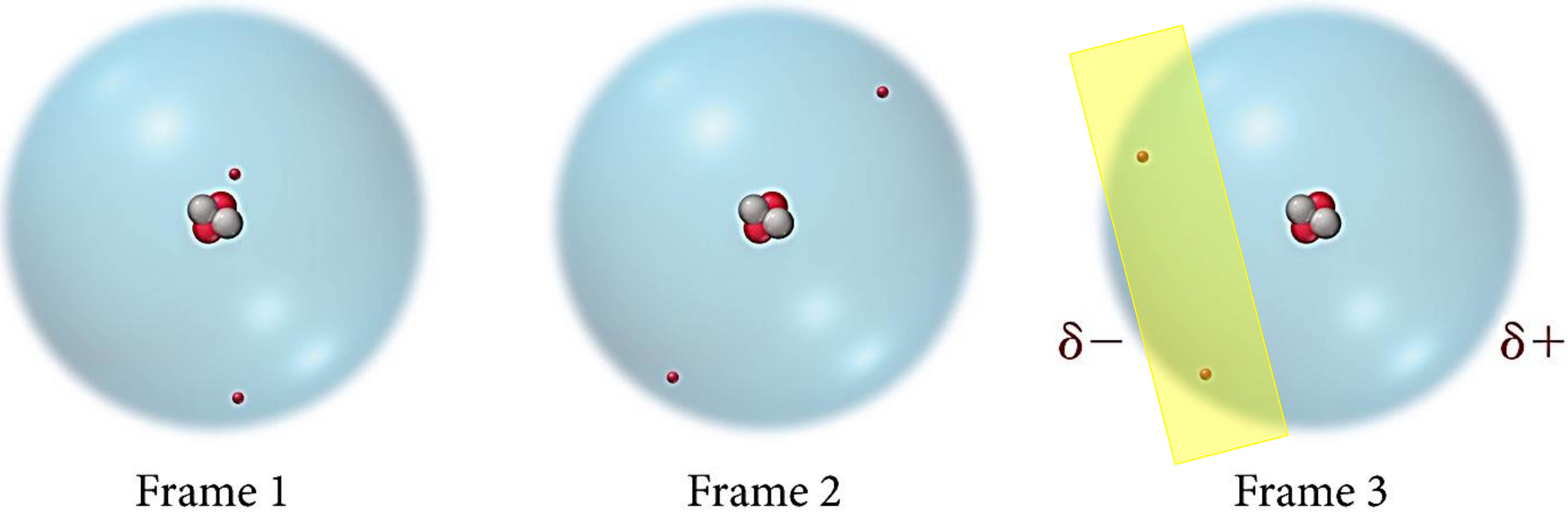
London Dispersion Forces

London force attractions

The **<u>temporary (or instantaneous)</u>** **separations of charge** that lead to the attraction of one nonpolar/noble gas molecule to its neighbors.

Fritz London
1900-1954

London Dispersion Forces



London Dispersion Forces

Electrons are not stationary – they move randomly.

It is possible to have temporary unequal distribution of e$^-$'s.

- Region with excess electron density has partial (–) charge
- Region with depleted electron density has partial (+) charge

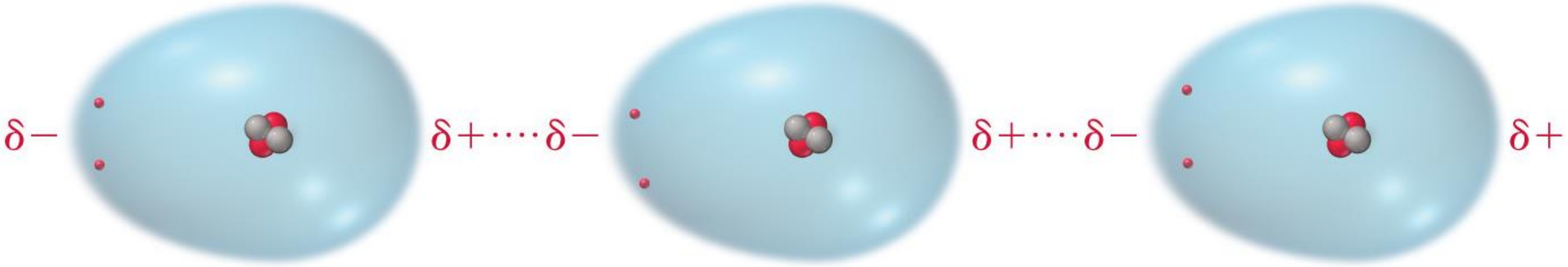
Results in a temporary dipole.

Called dispersion forces (aka London Dispersion Forces)

London Dispersion Forces

All molecules and atoms will have them.

As a temporary dipole is established in one molecule, it induces a dipole in all the surrounding molecules.



Size of the Induced Dipole

The magnitude of the induced dipole depends on several factors.

DO NOT SAY MORE ELECTRONS, BIGGER, LARGER MASS OR SIZE!

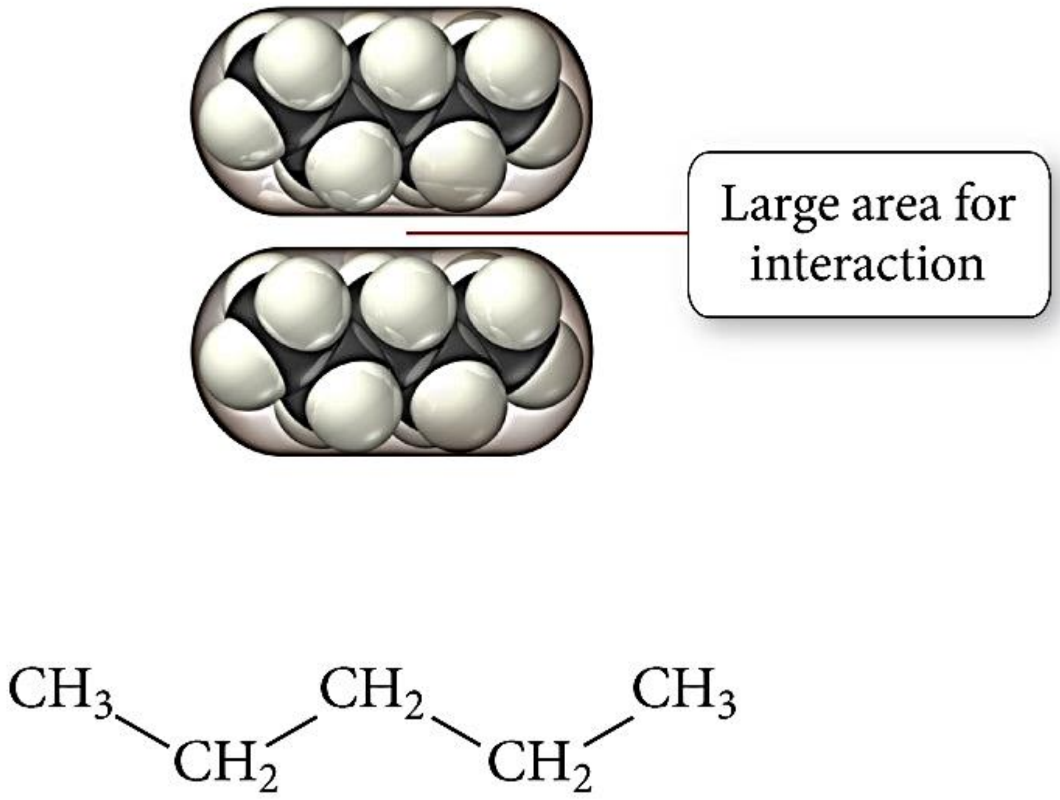
Polarizability of the electrons

- Volume of the electron cloud
- USUALLY: More electrons = larger electron cloud = increased polarizability = stronger attractions

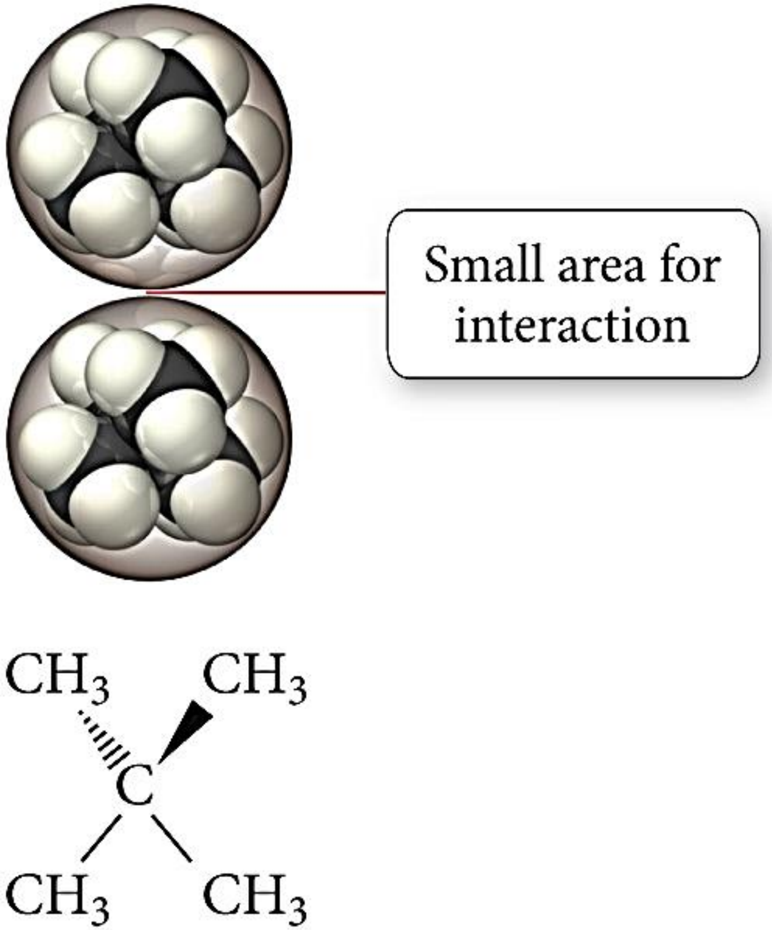
Shape of the molecule

- More surface area for interactions = larger induced dipole = stronger attraction

Effect of Surface Area on Size of LDF



(a) *n*-Pentane



(b) Neopentane

Effect of e- Cloud Size on Size of LDF

- Noble gases are all nonpolar atomic elements.

- The stronger the attractive forces between the molecules, the higher the boiling point will be.

TABLE 11.3 Boiling Points of the Noble Gases

Noble Gas	Boiling Point (K)
He	4.2
Ne	27
Ar	87
Kr	120
Xe	165

DON'T TALK ABOUT MASS!!!

Effect of e- Cloud Size on Size of LDF

As the number of electrons increase, the size of the electron cloud increases and it is more “polarizable” – more likely to result in unequal electron distribution. Therefore, the strength of the dispersion forces increases.

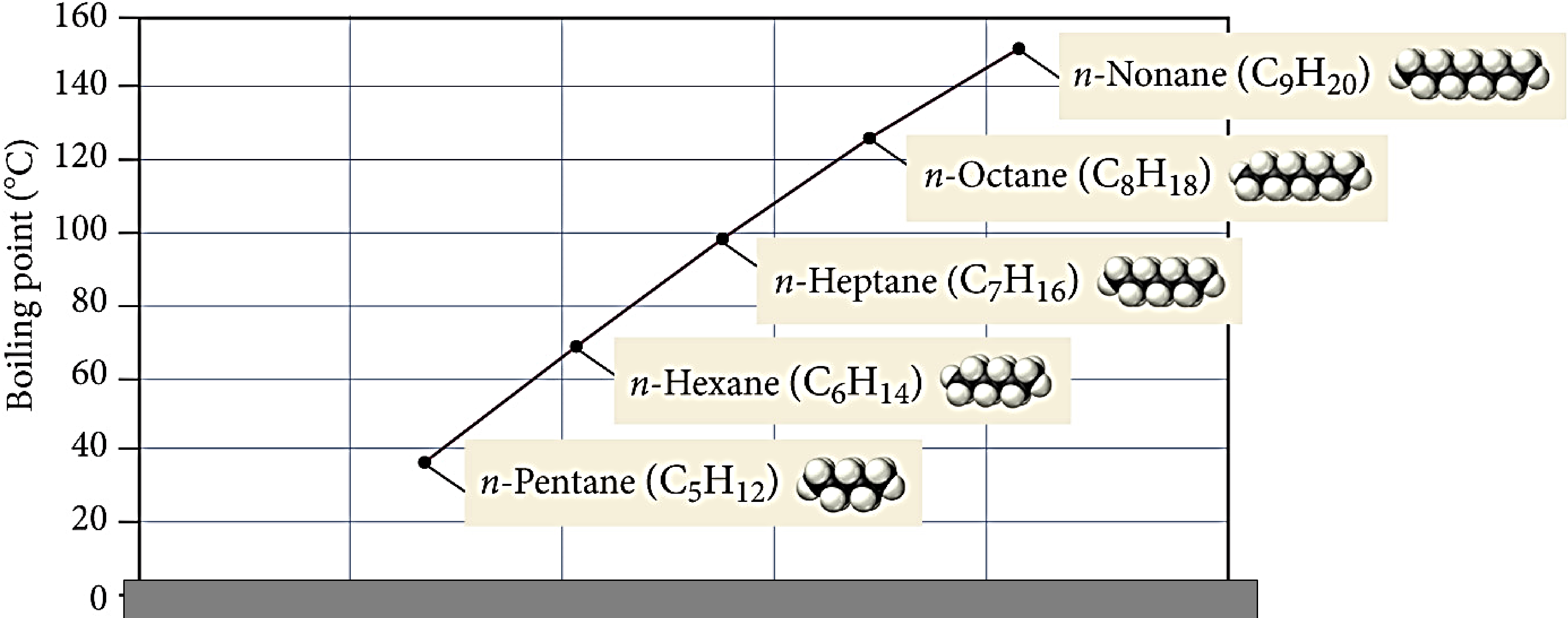
The stronger the attractive forces between the molecules, the higher the boiling point will be.

TABLE 11.3 Boiling Points of the Noble Gases

Noble Gas	Boiling Point (K)
He	4.2
Ne	27
Ar	87
Kr	120
Xe	165

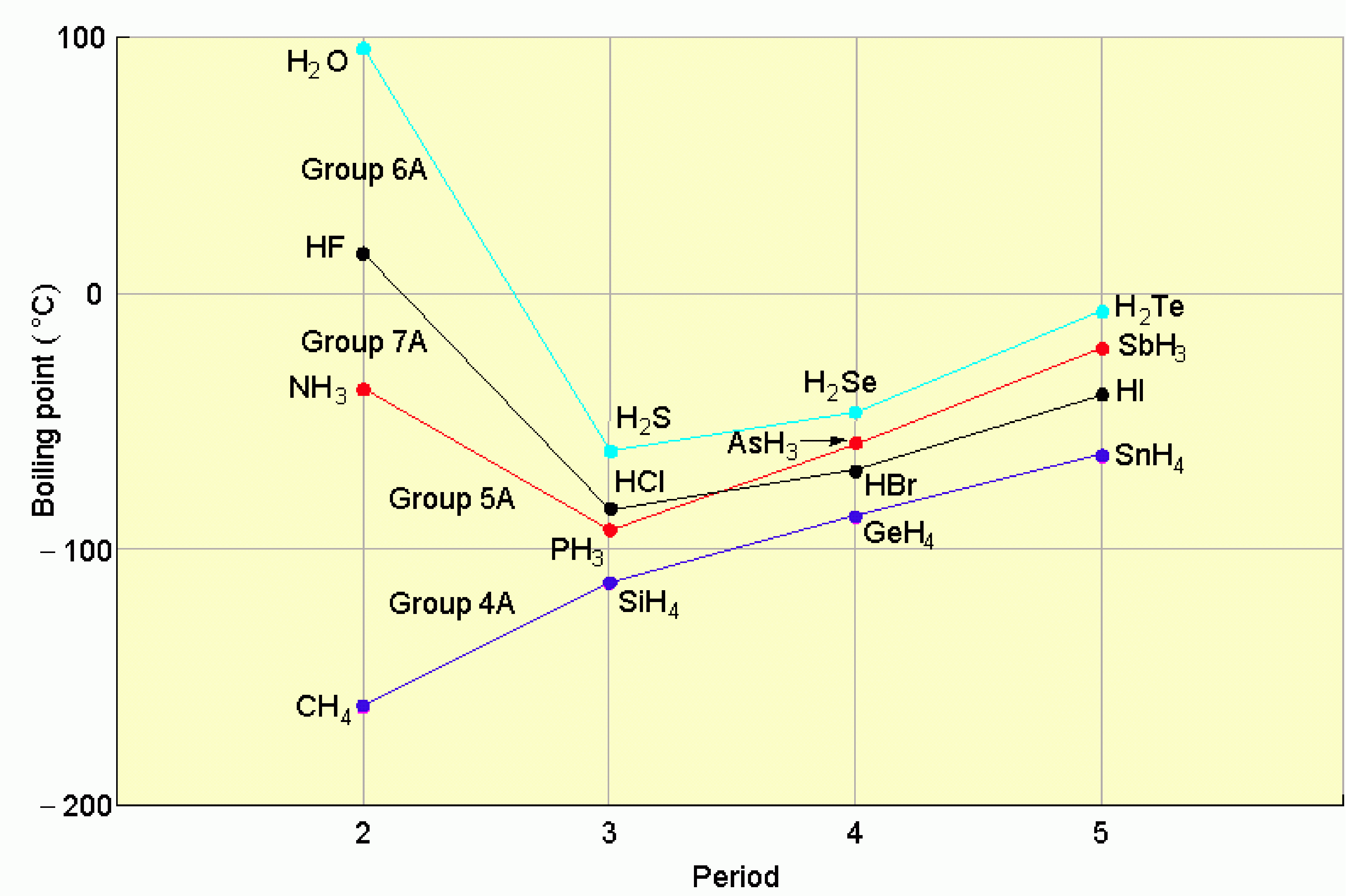
DON’T TALK ABOUT MASS!!!

Boiling Points of n-Alkanes



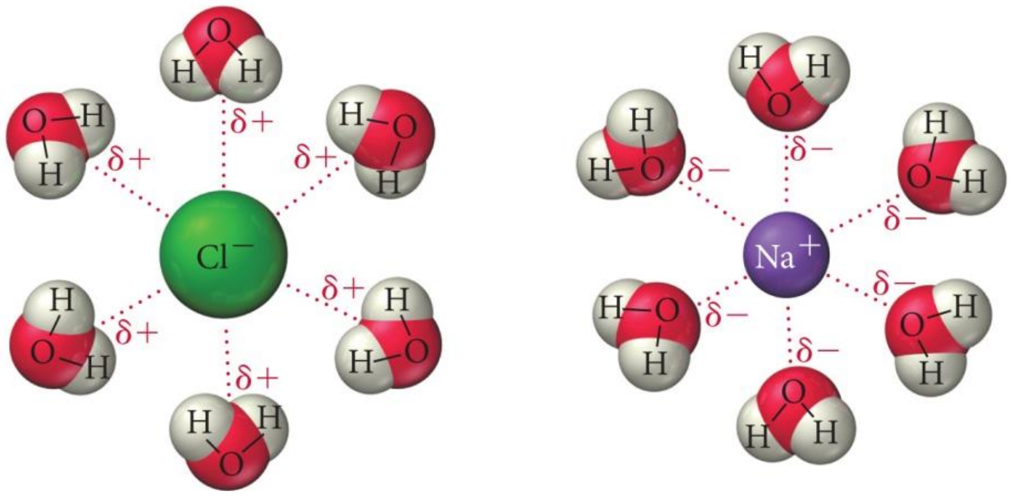
DON'T TALK ABOUT MASS!!!

BP as a Measure of IMFs



Ion-Dipole Attraction

In a mixture, ions from an ionic compound are attracted to the dipole of polar molecules.

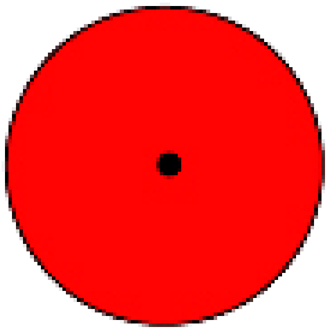


The strength of the ion–dipole attraction is one of the main factors that determines the solubility of ionic compounds in water.

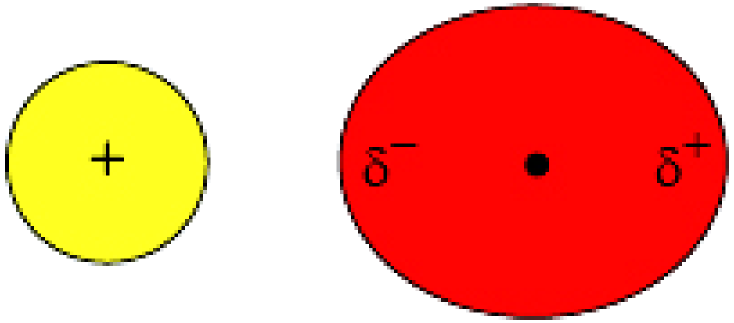
Ion Induced Dipole

An ion can induce a dipole in a nonpolar molecule.

By attracting the electrons in the nonpolar molecule the ion causes the nonpolar molecule to become slightly polar.



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

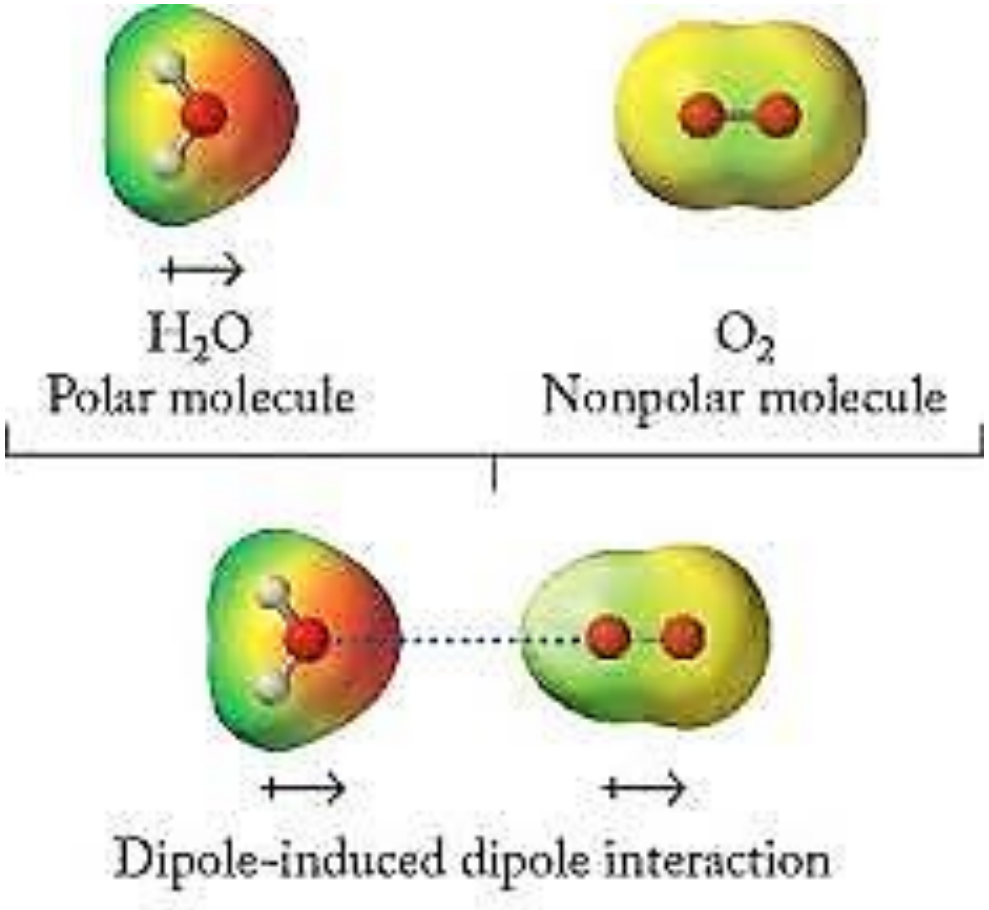


Upon approach of a charged ion, electrons in the atom respond and the atom develops a dipole.

Dipole Induced Dipole

An dipole can induce a dipole in a nonpolar molecule.

By attracting the electrons in the nonpolar molecule the dipole causes the nonpolar molecule to become slightly polar.



<u>Be Careful When Ranking Things</u>

- It can be hard to rank the strength of IMFs in various molecules without lab data like BP or MP.
- AP will usually give you data!
- Don't argue with their data!
- **A ton of a weak force can result in a larger <u>sum</u> of attractive force than expected!**

Be Careful When Listing Things

- Don't just list the dominant IMF!
- **List ALL the forces**!
  - Water = LDF, DP-DP, H-bond
  - CO_2 = LDF

- How do you know when to just report one versus all of them? Who knows! Look for key words, err on the side of listing all unless a key word implies they just want dominant.

Be Careful with Phrasing Answers

- When comparing substances you **HAVE TO MENTION BOTH THE MOLECULES** in the question! They specifically wont give points if you only mention one.
  - ***Example:*** *Why does H_2O have a higher BP than CO_2*
  - ***Bad answer:*** *H_2O has a higher BP because it has H-bonding.*
  - ***Good answer:*** *While CO_2 has LDF forces, H_2O has LDF AND H-Bonding. The H-Bonding in H_2O results in more intermolecular attractions so it has a higher BP than CO_2 does.*

<u>Summary – London Forces</u>

- The weakest of the intermolecular attractions.
- Present in all molecules and atoms.
- Magnitude increases with increasing polarizability and surface area.
- There can be so many LDFs that the **<u>sum</u>** of all the LDFs makes higher BP than expected.

Summary – Dipole-Dipole and H-Bonding

- Polar molecules have LDF and dipole–dipole forces.

- H-Bonds are the strongest of the intermolecular attractive forces a pure substance can have.

- H-bonds will be present when a molecule has H directly bonded to either O, N, or F atoms.

Summary – Ion-Dipole

- Present in mixtures of ionic compounds with polar molecules.
- Often the strongest intermolecular attraction.
- Especially important in aqueous solutions of ionic compounds.

Summary – Induced Dipoles

- **Ion induced Dipole** attractions are when an ion can induce a dipole in a normally nonpolar molecule.

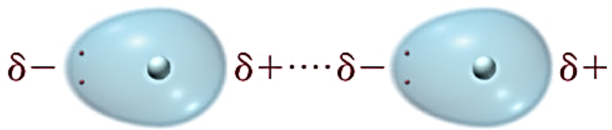
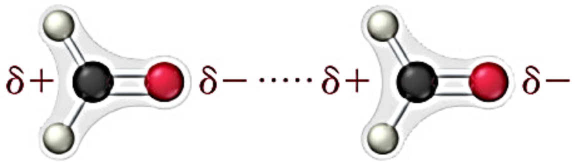
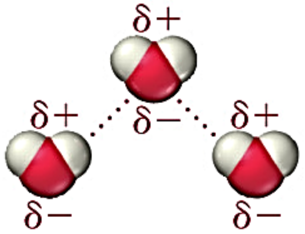
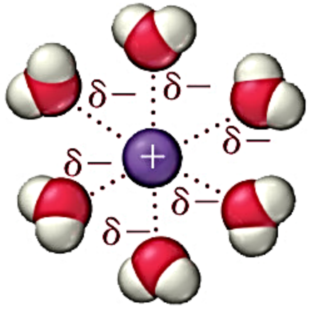
- **Dipole induced Dipole** attractions are when a dipole can induce a dipole in a normally nonpolar molecule.

- Be very careful with the difference between “Ion-Dipole” and “Ion Induced Dipole” - they are not the same! And be careful about the difference between “Dipole-Dipole” and “Dipole Induced Dipole” – they are not the same

Summary

Generic Ranking of Common IMFs

TABLE 11.4 Types of Intermolecular Forces

Type	Present in	Molecular perspective	Strength
Dispersion	All molecules and atoms		
Dipole-Dipole	Polar molecules		
Hydrogen Bonding	Molecules containing H bonded to F, O, or N		
Ion-Dipole	Mixtures of ionic compounds and polar compounds		

YouTube Link to Presentation:

https://youtu.be/i4JT1_E9kCs