Sections 12.4 – 12.5
Intermolecular Forces

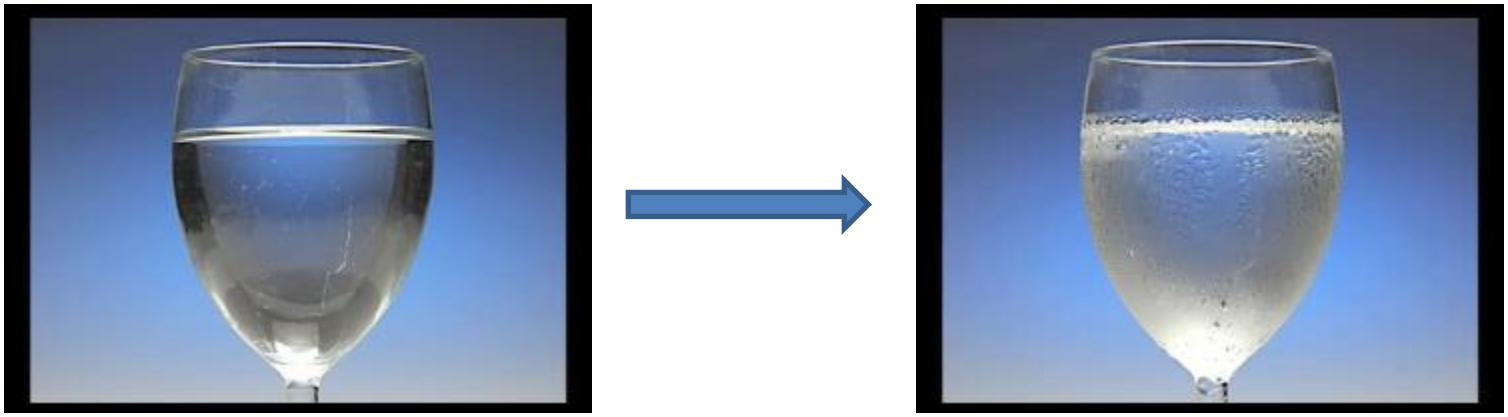
Intermolecular Forces

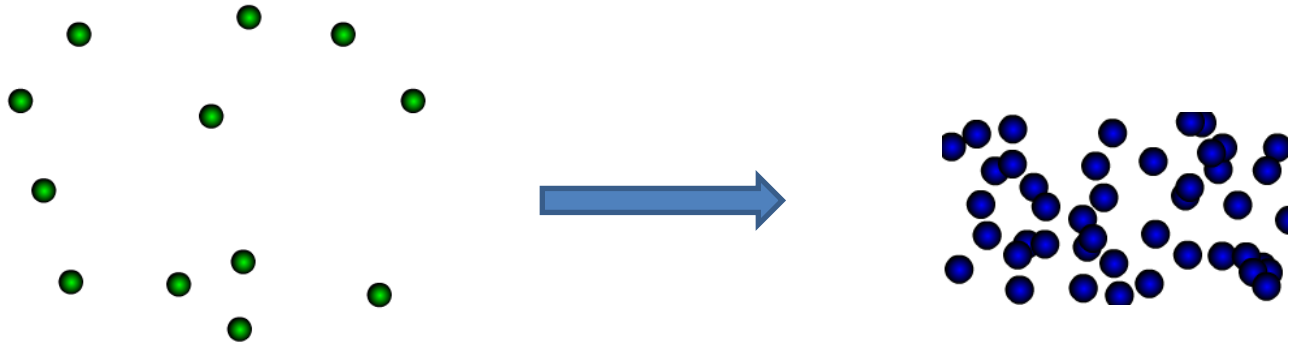
In these sections…

a. Types of Intermolecular Forces
    1. Dipole – Dipole Forces
    2. Hydrogen Bonding
    3. Dipole-Induced Dipole Forces
    4. Induced Dipole – Induced Dipole Forces

b. Relating Molecular Structure, IMFs, and Properties of Liquids

When near a cold surface, gas phase water molecules condense to form a liquid. Why does this happen?





Intermolecular Forces: Summary

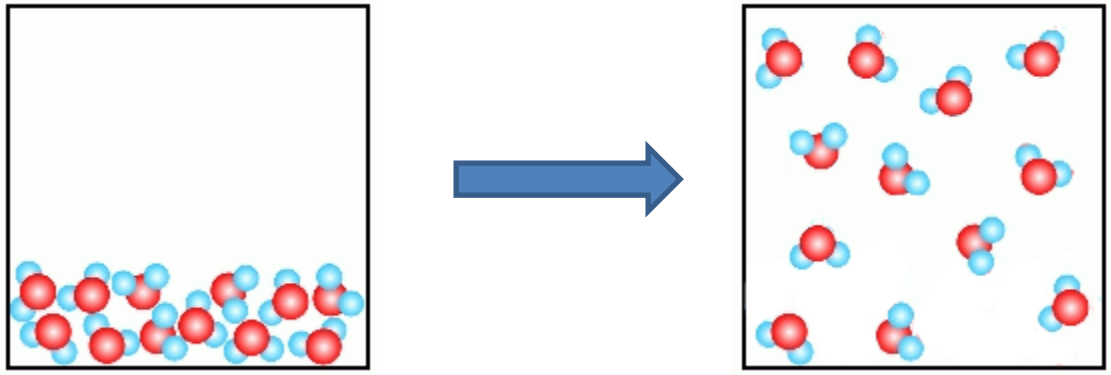
All due to attraction of opposite charges on adjacent molecules.

Compare with covalent bonds 250 - 400 kJ/mol

Type	Origin	Relative Strength
Dipole-Dipole	Partial charges on two polar molecules.	≈2-10 kJ/mol
Hydrogen Bonding (a special case of dipole-dipole force)	Partial charges resulting from N-H, O-H, or F-H bonds on adjacent molecules.	25-50 kJ/mol
Dipole-Induced Dipole	Partial charges on one molecule inducing partial charges on a nonpolar molecule	
Induced Dipole-Induced Dipole	Two nonpolar molecules inducing momentary partial charges when near each other	<5 kJ/mol for small molecules

Intermolecular Forces vs. Covalent Bonds

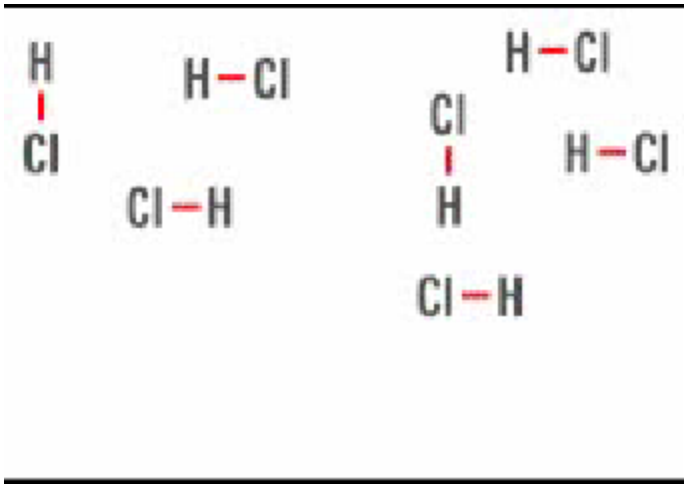
What happens to liquid water when it boils?



What does ***NOT*** happen to liquid water when it boils?

Dipole – Dipole Forces

Partial charges on two polar molecules attract.



Hydrogen Bonding: Really Strong Dipole – Dipole Forces

Occurs when a molecule has one of these bonds:

N-H
O-H
F-H

Why?

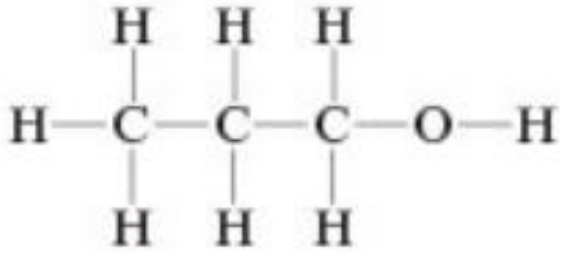
Hydrogen Bonding: Really Strong Dipole – Dipole Forces

Occurs when a molecule has one of these bonds:

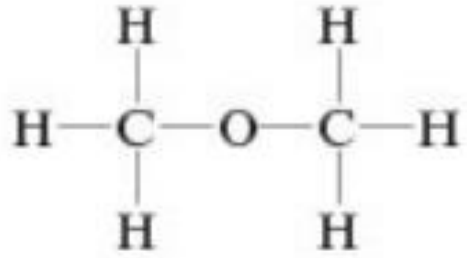
N-H
O-H
F-H

For which of these compounds is hydrogen bonding expected?

Propanol



Dimethyl ether



Hydrogen Bonding: Really Strong Dipole – Dipole Forces

Occurs when a molecule has one of these bonds:

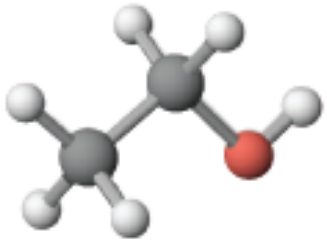
N-H

O-H

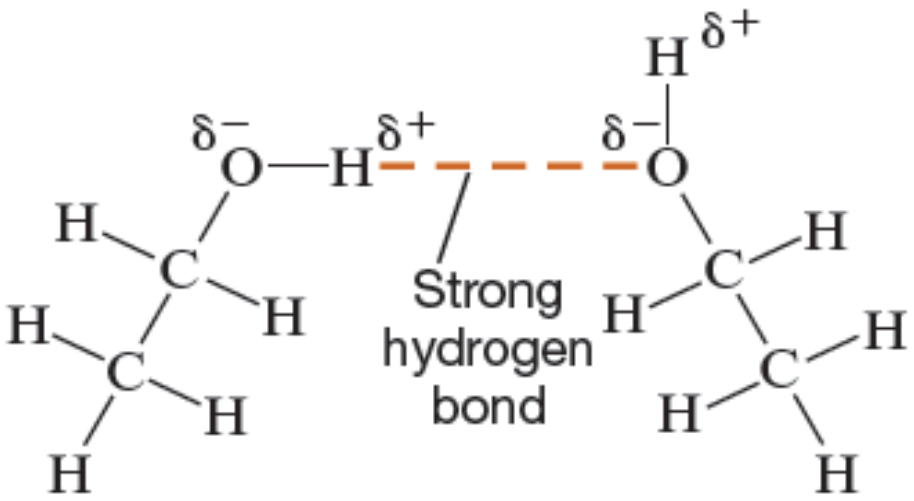
F-H

Which are stronger:

hydrogen bonds or normal covalent bonds?

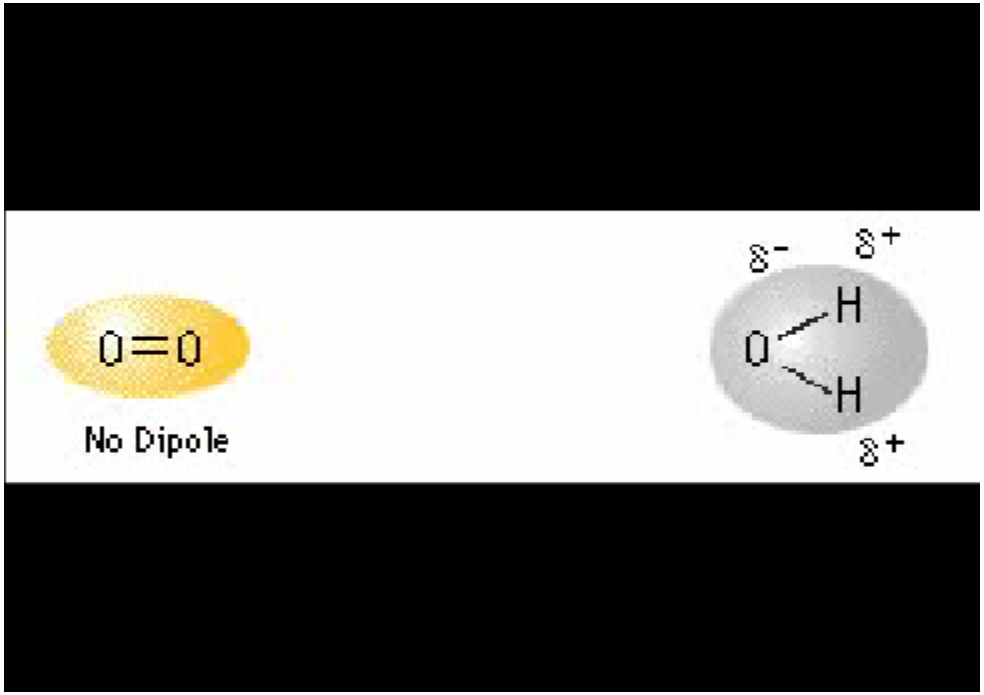


Ethanol
Boiling point
78.29 °C



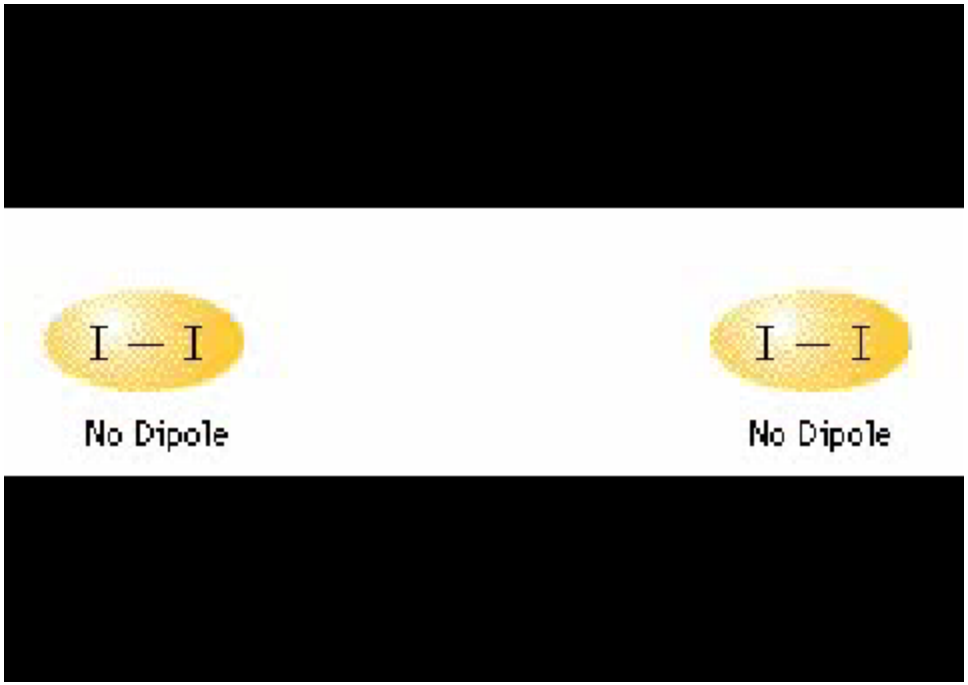
Dipole – Induced Dipole Forces

Partial charges on one molecule inducing partial charges on a nonpolar molecule.



Induced Dipole – Induced Dipole Forces

Two nonpolar molecules inducing momentary partial charges when near each other.



These forces are also called:
London Dispersion Forces, or just **Dispersion Forces**.

Return to: Properties of Liquids

Enthalpy of Vaporization: Energy required to vaporize a liquid.

Vapor Pressure: The gas pressure of a vapor
(a vapor is a gas that comes from a liquid vaporizing.)

Boiling Point: Temperature at which vapor pressure reaches
external atmospheric pressure.

Surface Tension: The tendency of a liquid surface to resist change.

Viscosity: The resistance of a liquid to flowing.

These properties all depend on IMF strength.

Return to: Properties of Liquids

These properties all depend on IMF strength.

As IMF Strength **Increases**:

Enthalpy of Vaporization:	increases
Vapor Pressure:	decreases
Normal Boiling Point:	increases
Surface Tension:	increases
Viscosity:	kind of increases, but not always

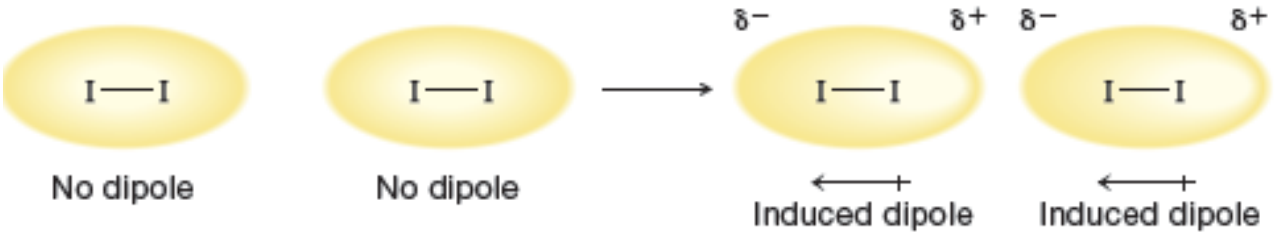
Different Liquids have Different Properties

CH_3CH_2OH

$H_2O + CH_3CH_2OH$

Which has stronger IMFs?

IMF Trends: Dispersion Forces



These forces arise from electron clouds being “polarized.”

Dispersion force strength increases with increasing “polarizability.”

Polarizability increases with increasing atom or molecular size.

IMF Trends: Dispersion Forces

Table 11.5.1 Molar Mass, ΔH°_{vap}, and Boiling Point for Some Nonpolar Species

Compound	Molar Mass (g/mol)	ΔH°_{vap} (kJ/mol)	Boiling Point (°C)
He	4.0	0.08	−268.9
Ne	20.3	1.7	−246.1
N_2	28.0	5.6	−195.8
O_2	32.0	6.8	−183.0
Ar	39.9	6.4	−185.9
Cl_2	70.9	20.4	−34.0
Br_2	159.8	30.0	58.8

As molecule size increases, IMF strength increases.

IMF Trends: Dispersion Forces

Table 11.5.2 Selected Physical Properties of Some Hydrocarbons

Molecular Formula	Name	$\Delta H°_{vap}$ (kJ/mol)	Boiling Point (°C)
CH_4	Methane	8.2	−161
C_2H_6	Ethane	14.7	−88
C_3H_8	Propane	19.0	−42
C_6H_{14}	Hexane	28.9	69
C_8H_{18}	Octane	34.4	126
$C_{10}H_{22}$	Decane	38.8	174
$C_{18}H_{38}$	Octadecane	54.5	317

As molecule size increases, IMF strength increases.

IMF Trends: Dipole – Dipole Forces

Dipole forces are stronger than corresponding induced dipole forces.

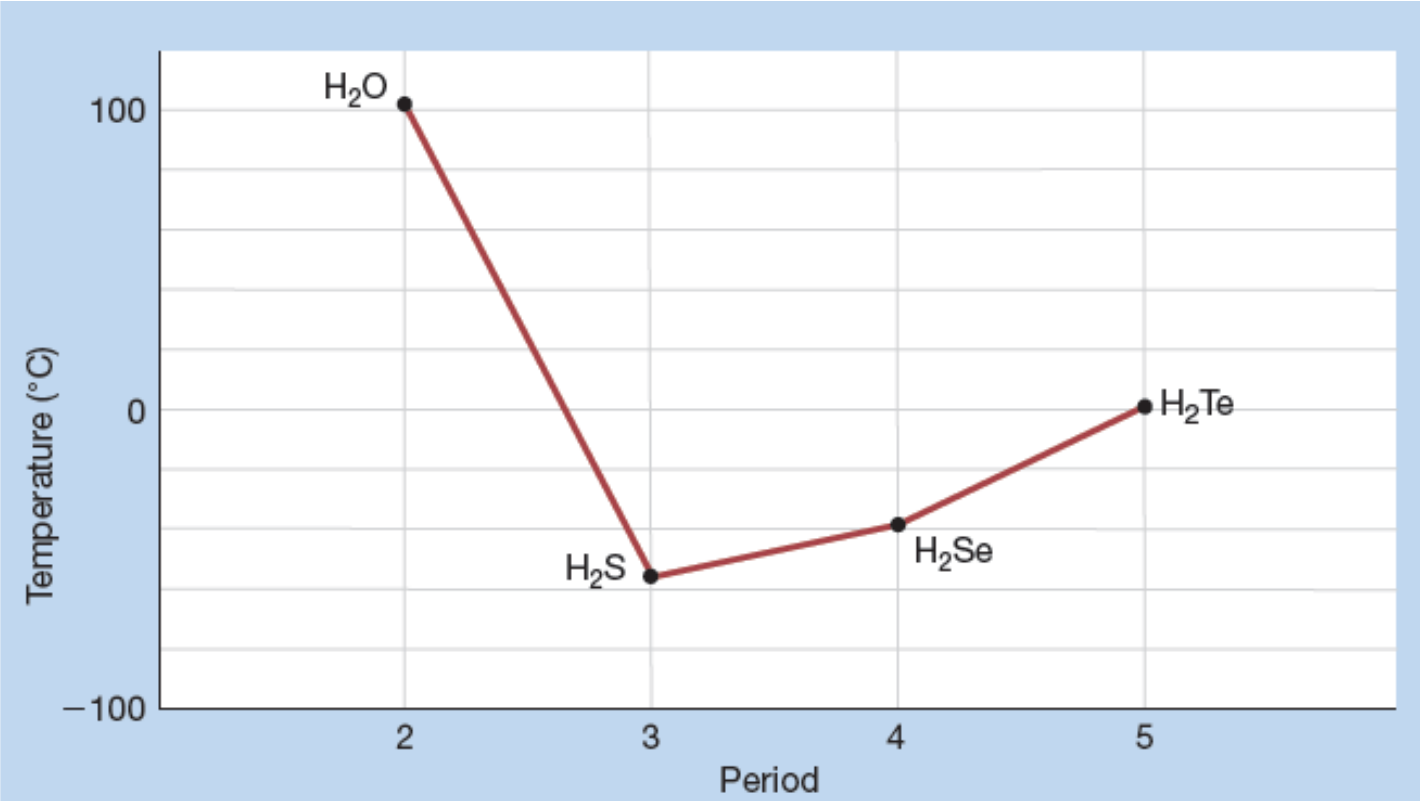
Table 11.5.3 Molar Masses and Boiling Points of Some Polar and Nonpolar Substances

Nonpolar			Polar		
	Molar Mass (g/mol)	Boiling Point (°C)		Molar Mass (g/mol)	Boiling Point (°C)
N_2	28	−196	CO	28	−192
SiH_4	32	−112	PH_3	34	−88
GeH_4	77	−90	AsH_3	78	−62
Br_2	160	59	ICl	162	97

But the effect is not that large, unless ...

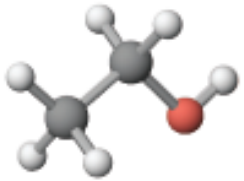
IMF Trends: Hydrogen Bonding

Compounds with hydrogen bonding have much stronger IMFs than compounds of similar size.

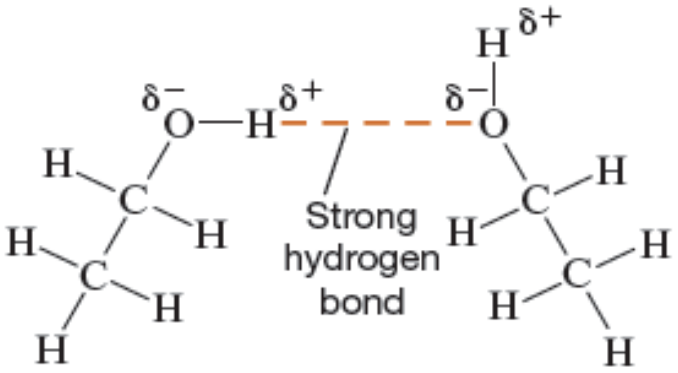


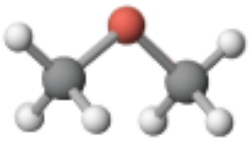
IMF Trends: Hydrogen Bonding

Compounds with hydrogen bonding have much stronger IMFs than compounds of similar size.

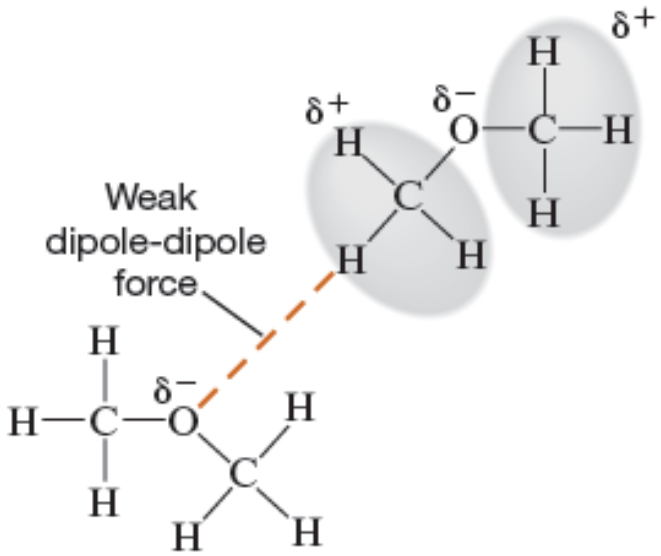


Ethanol
Boiling point
78.29 °C





Dimethyl ether
Boiling point
–24.8 °C



All Compounds Experience Dispersion Forces Even if they are polar

This molecule experiences hydrogen bonding, but its large size means its properties are controlled by its dispersion forces.