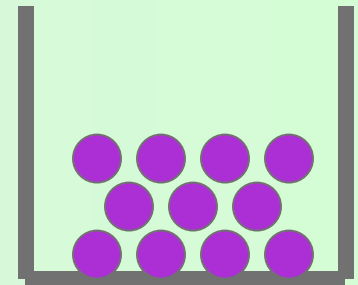
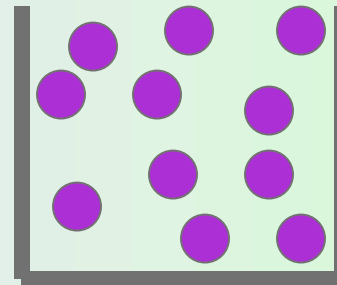
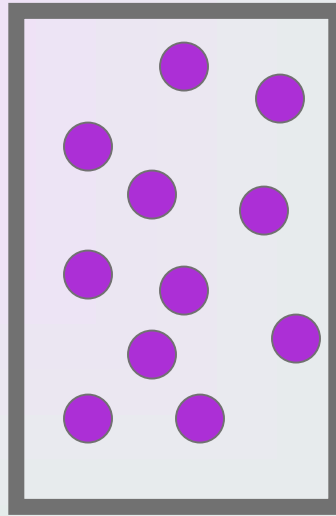


The kinetic Molecular Theory of Liquids and solids

Characteristics properties of gases, liquids, and solids



gas

liquid

solid

Definite volume

no

yes

yes

Definite shape

no

no

yes

density

low

high

high

compressibility

high

slight

no

Molecular motion

free

slide

vibrate

. States of matter

solid

Liquid

Gas

- the various states of matter can be understood by examining attractive forces between molecules**

Intermolecular Forces

Intermolecular Forces

Attractive forces between molecules

Intermolecular Forces

ion-ion

ion-dipole

ion-induced dipole

dipole-dipole

dipole-induced dipole

induced dipole-induced dipole

Intermolecular Forces

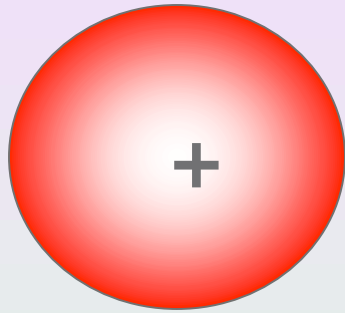
Van der Waals forces

dipole-dipole

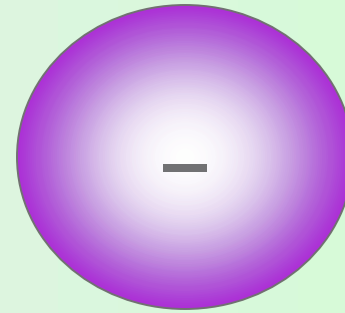
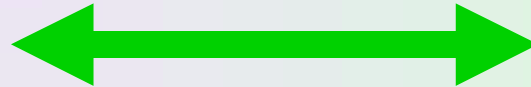
dipole-induced dipole

induced dipole-induced dipole

Ion-ion attractive force



cation



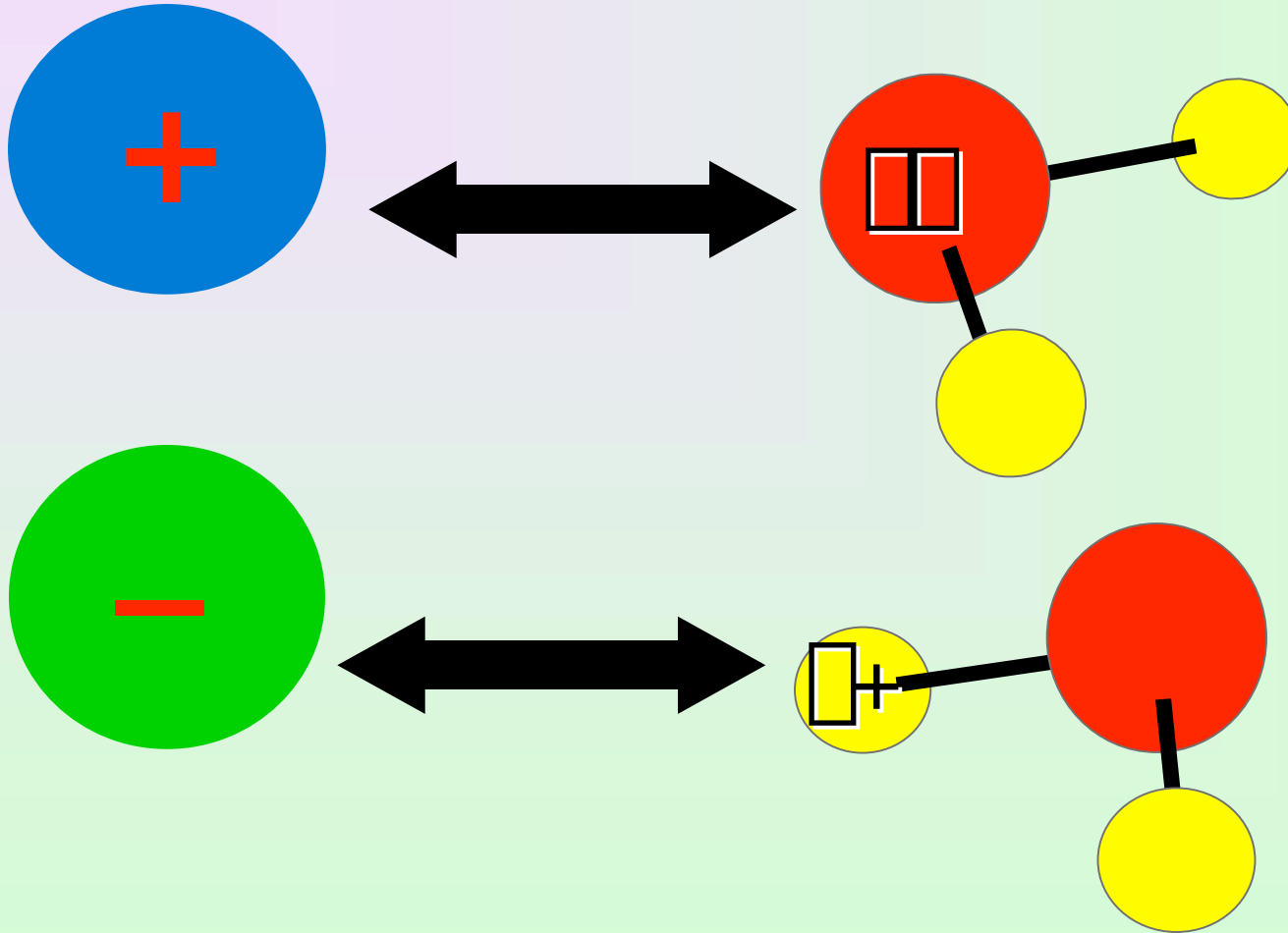
anion

- **is an ionic bond**
- **very strong**

ion-dipole attractive forces

**attractive forces between an ion and a
polar molecule**

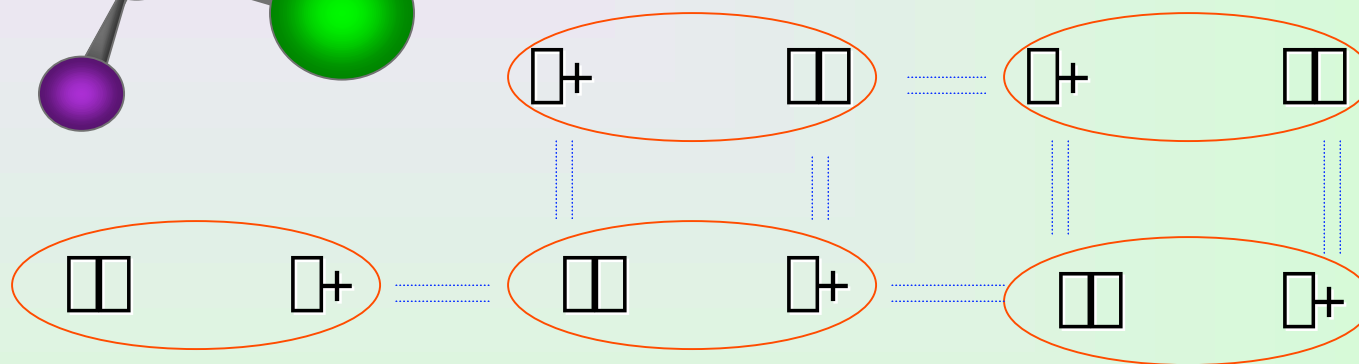
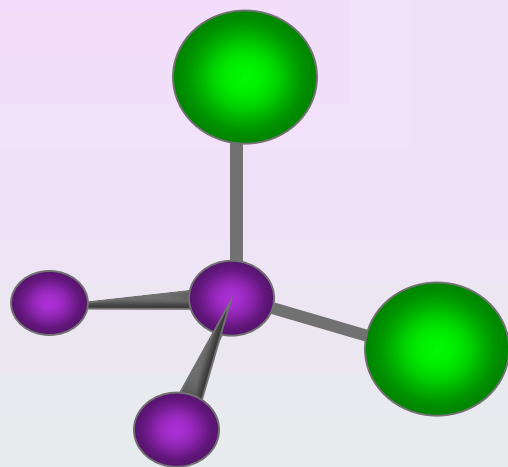
ion-dipole attractive force



dipole -dipole attractive forces

attractive forces between polar molecules

dipole-dipole attractive force

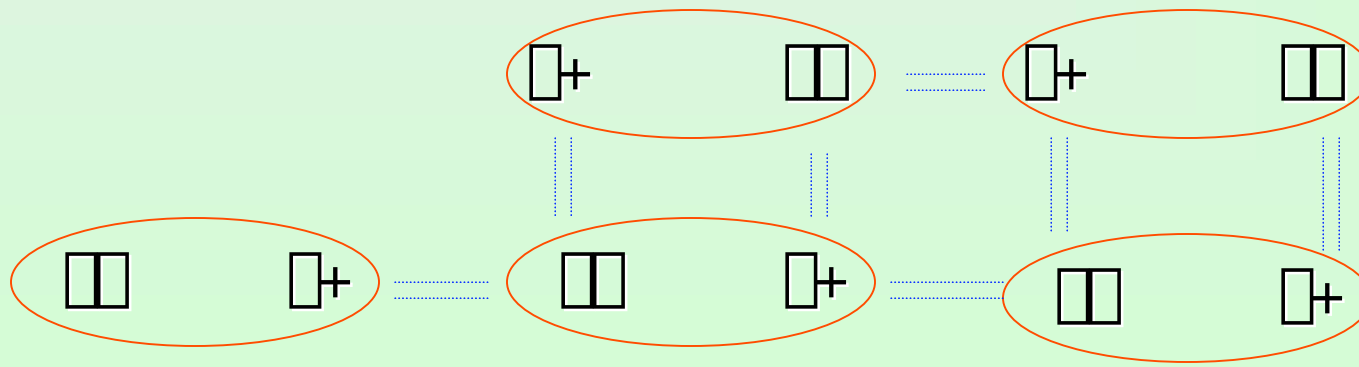
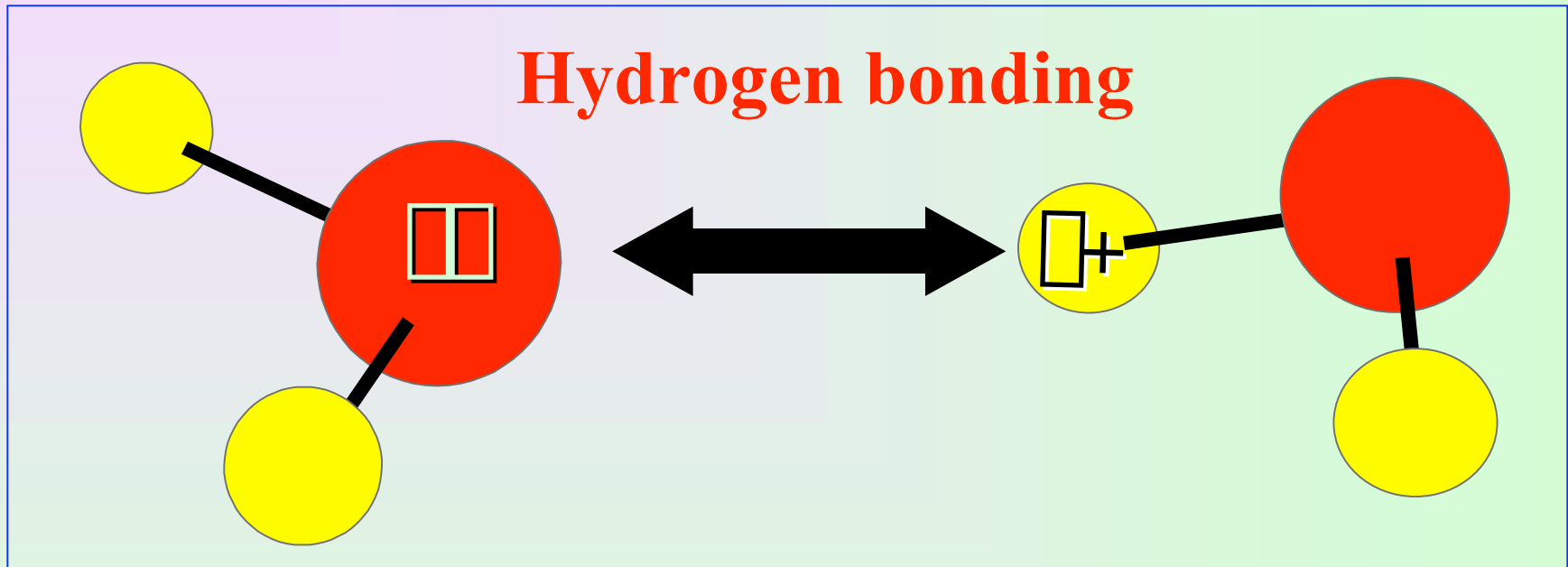


Hydrogen bonding

A special type of dipole- dipole interaction

A very strong dipole interaction

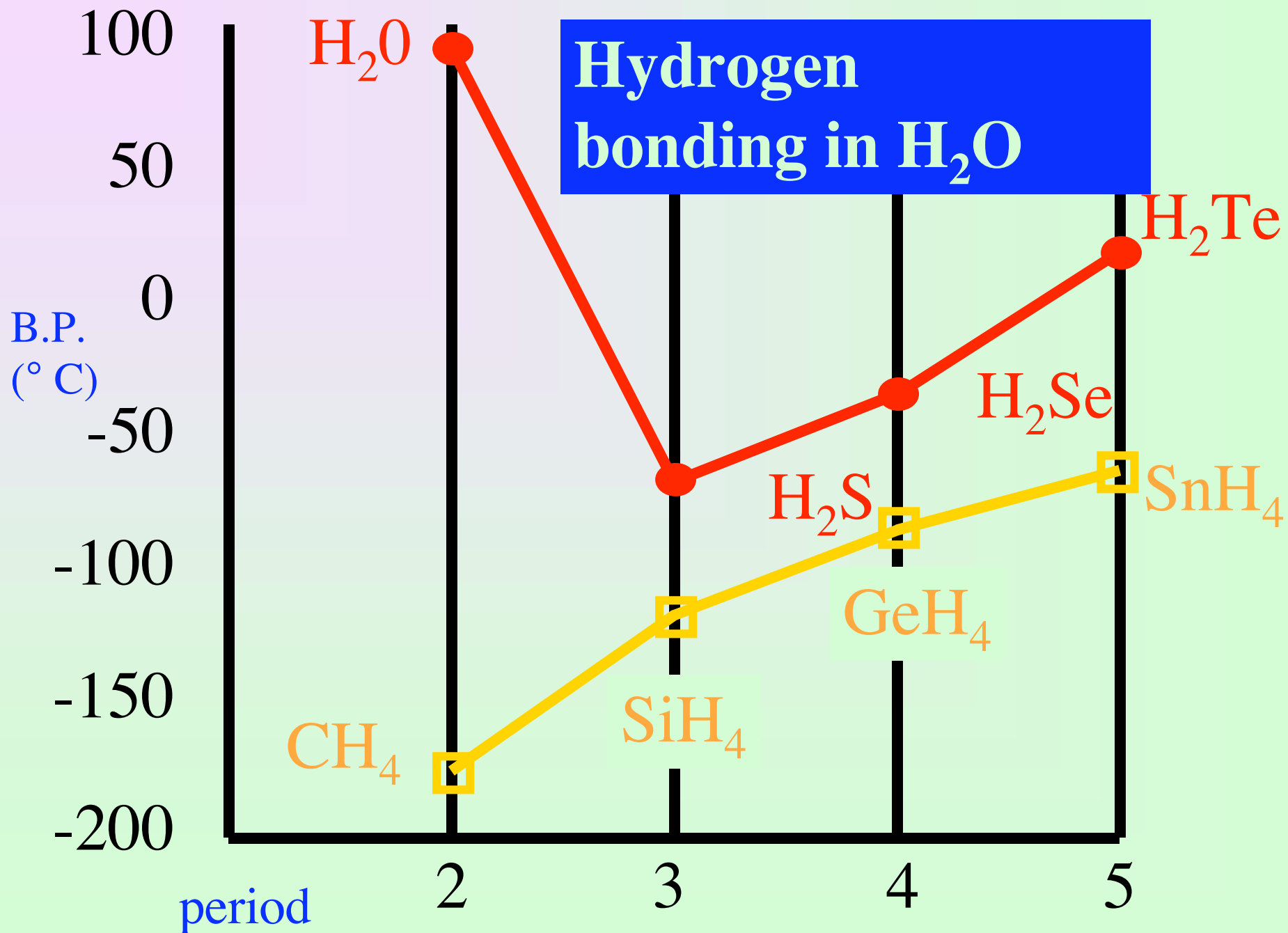
dipole-dipole attractive force



Importance of Hydrogen Bonding

- boiling point depends on intermolecular forces in liquid state

compound	MW	Δ	Bp, °C
CH ₃ CH ₂ CH ₃	44	0	-42
CH ₃ CH ₂ OH	46	1.7	+78



Hydrogen bonding important in compounds with

OH bonds

water, alcohols, acids, carbohydrates

NH bonds

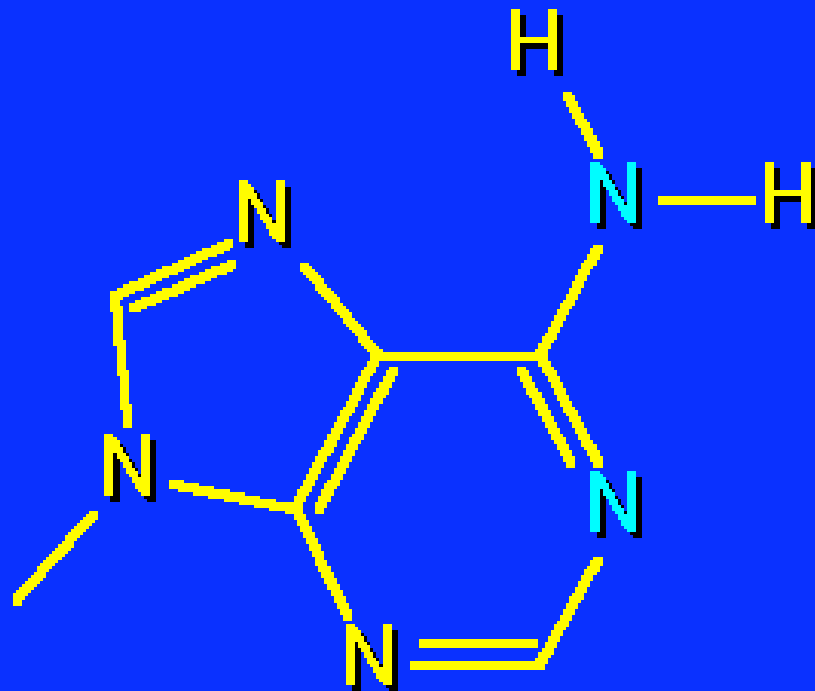
ammonia, amines, peptides, proteins,
nucleic acids

FH bonds

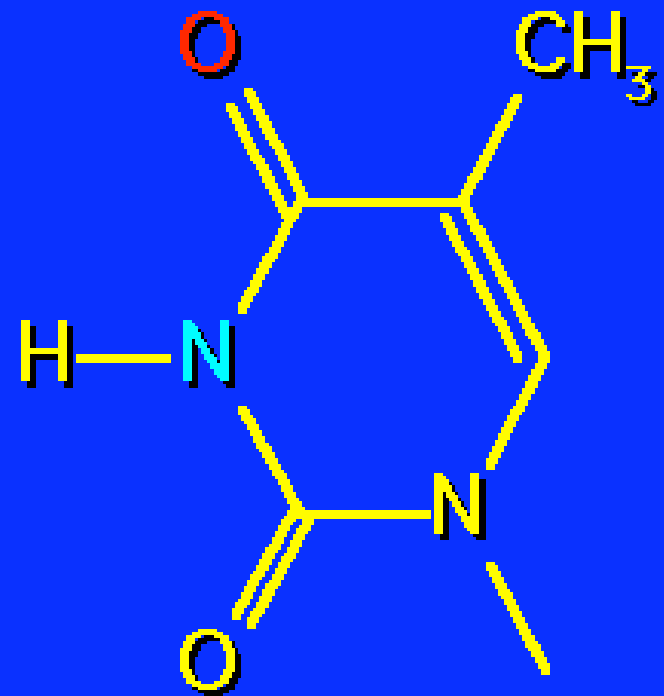
Importance of Hydrogen Bonding

- hydrogen bonding in
 - proteins
 - nucleic acids (DNA and RNA)

Base pairing in nucleic acid bases

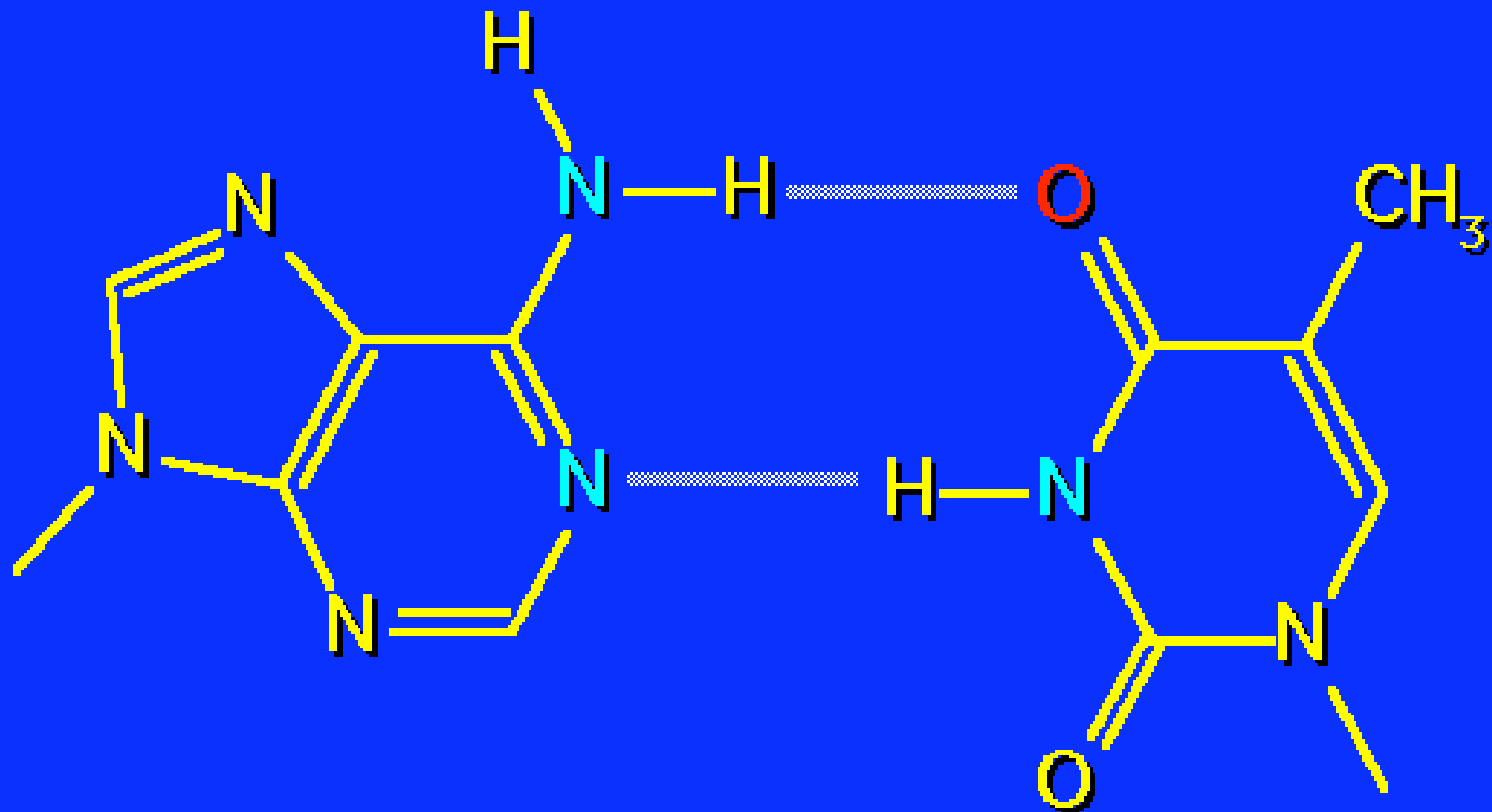


Adenine



Thymine

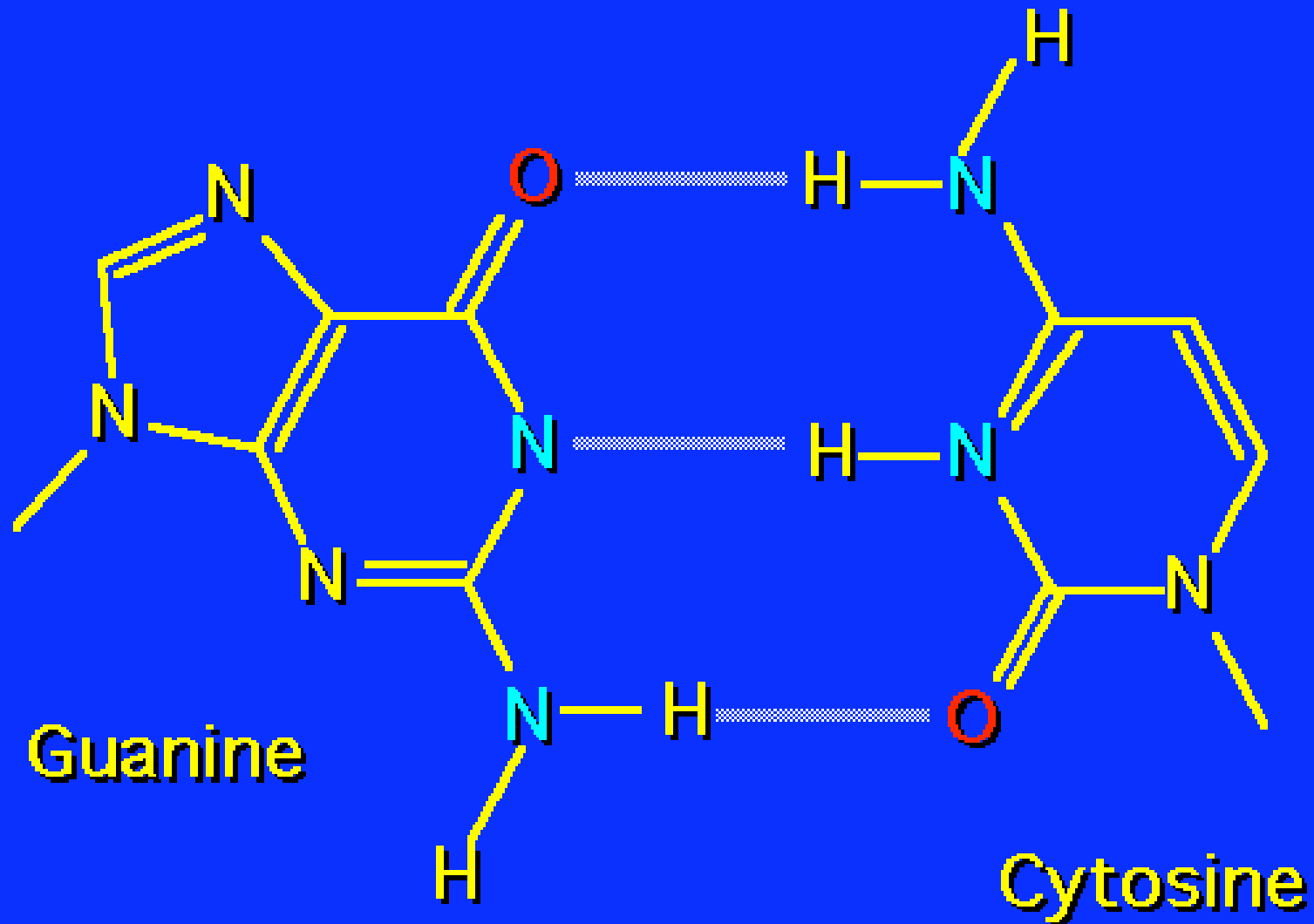
Base pairing in nucleic acid bases



Adenine

Thymine

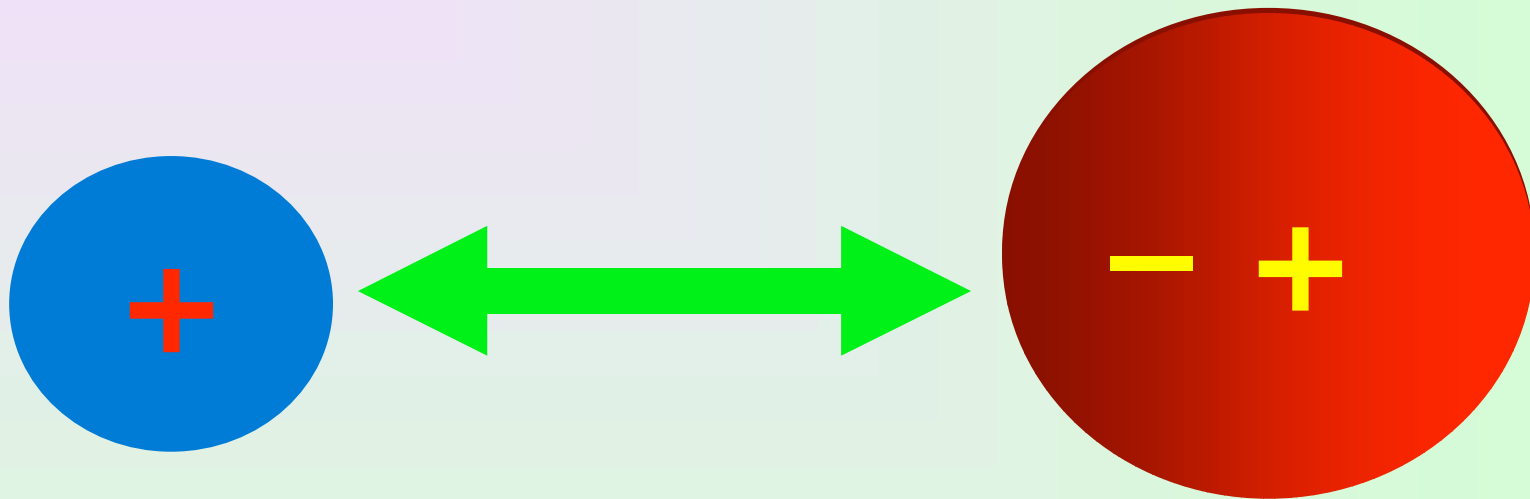
Base pairing in nucleic acid bases



Dispersion forces

attractive forces that result from temporary dipoles induced in an atom or molecule

ion-induced dipole attractive force



Polarizability: the ease with which the electron distribution surrounding an atom is distorted by an external electric field

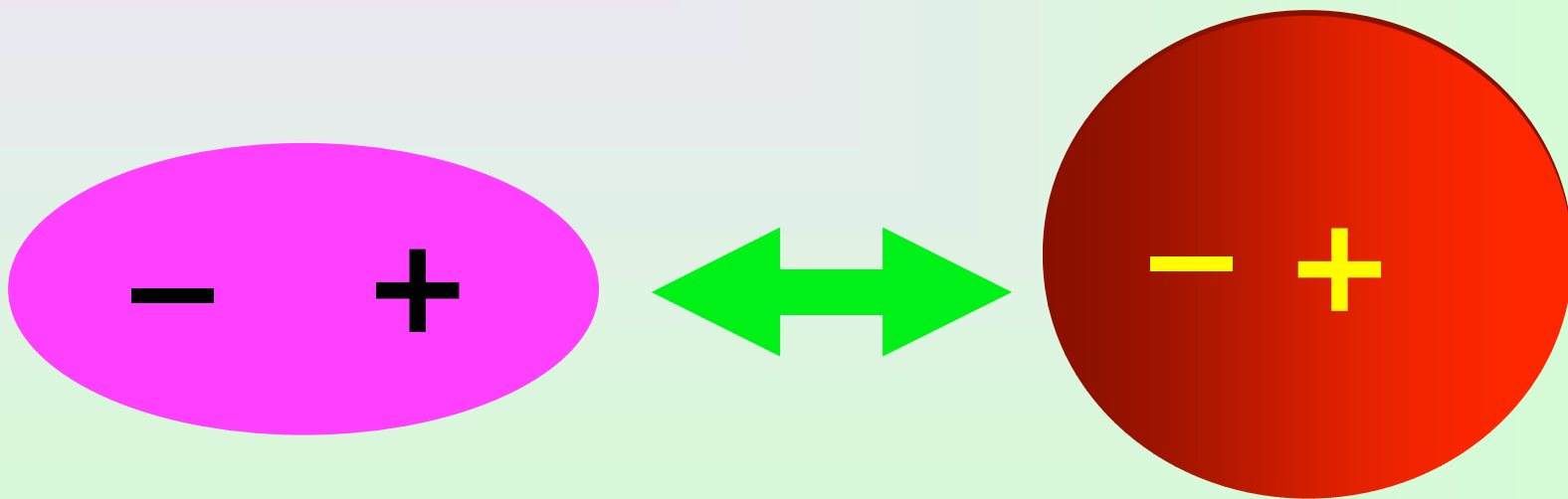
Polarizability

- increases with size of atom

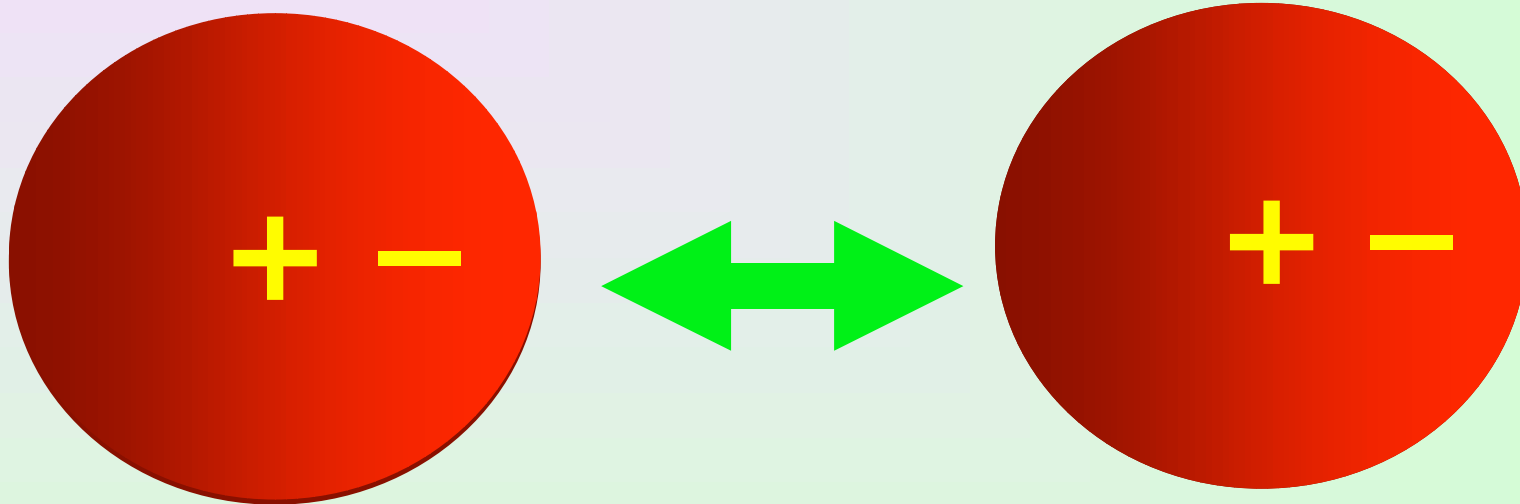
fluorine very nonpolarizable (“hard”)

iodine very polarizable (“soft”)

Dipole-induced dipole attractive forces



Induced dipole-induced dipole attractive forces (*London Forces*)



Boiling Points

depend on intermolecular attractive forces in liquid state

Example:

F_2

Cl_2

Br_2

I_2



$$\Delta H^\circ = 62 \text{ kJ/mol}$$

This is a direct measure of the induced dipole-induced dipole attractions between I_2 molecules in the solid state

Melting points of similar nonpolar molecules

compound	Melting Point, °C
CF_4	-150
CCl_4	-23
CBr_4	90
CI_4	171

More electrons, more polarizable, stronger dispersion forces

Fluorine is very nonpolarizable, and dispersion forces involving fluorine are weak

compound	bp, ° C
CH₃CH₃	-89
CH₃CH₂F	-32
CH₃CHF₂	-25
CH₃CF₃	-47
CF₃CF₃	-78

Approximate magnitudes of intermolecular forces

Force	Energy, kJ/mol
ion-ion	500–1000
ion-dipole	40–600
ion-induced dipole	
dipole-dipole	5–25
dipole-induced dipole	2–10
induced dipole– induced dipole	0.05–40