BIO 311C
Spring 2010

Exam 1: in this room at this time on Friday, Feb. 12 (this Friday)

The last ~20 minutes of the Wednesday lecture period will be devoted to a review of the subject matter covered through today's lecture. More information about the exam will also be provided at that time.

Lecture 9 – Monday 8 Feb. 2010

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Levels of Organization within Living Cells

Populations of similar cells within an organism (tissue) or populations of unicellular organisms

living cells

↓

occlusions, cellular organelles, other cellular structures

↓

large organic molecules

↓

small molecules

↓

atoms

levels of organization considered in most detail in BIO 311C

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Chemistry as applied to living cells is especially concerned with:

A. the arrangements of atoms within and between biological molecules.
(chemical structures)

B. changes in the arrangements of atoms as they combine and dis-associate in various ways.
(chemical reactions)

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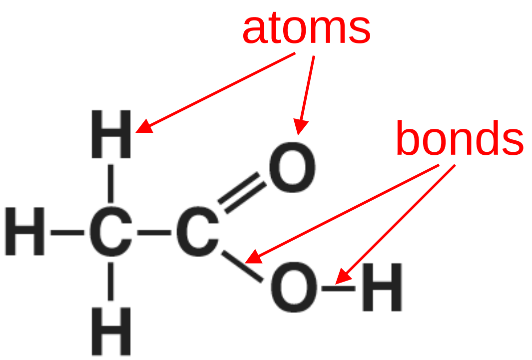
In order to appreciate the structures and functions of biomolecules in living cells, it is necessary to understand some features of:

- the individual atoms that are components of biomolecules,

- the bonds that hold the atoms of biomolecules together.



Acetic acid,
a small organic molecule

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Major Elements that occur in the Human Body

Symbol	Element	Atomic Number (See p. 29)	Percentage of Human Body Weight
O	Oxygen ←	8	65.0
C	Carbon ←	6	18.5
H	Hydrogen ←	1	9.5
N	Nitrogen ←	7	3.3
Ca	Calcium	20	1.5
P	Phosphorus ←	15	1.0
K	Potassium	19	0.4
S	Sulfur ←	16	0.3
Na	Sodium	11	0.2
Cl	Chlorine	17	0.2
Mg	Magnesium	12	0.1

Also see textbook Table 2.1, p. 32

Green arrows represent elements most abundant in biological molecules.

Know the chemical symbols for all elements shown in this table, and for the trace elements copper (Cu), iron (Fe), and manganese (Mn).

This list of relative abundance of elements in the human body does not exactly represent their relative abundance in living cells. For example, calcium and sodium levels are much lower in living cells than in their surrounding medium.

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Summary of Bond Characteristics of Typical Biological Molecules

Bond Type	Bond Length (Å)	Bond Angle (deg.)	Bond Strength (KJ/mol)
covalent	~ 1	~ 109	100 - 500 (typically ~400)
polar	several	N.A.*	N.A.
hydrogen	~ 3	~ 180	15 - 40 (typically ~40)
electrovalent	several	N.A.	N.A.
van der waals	< 3	N.A.	N.A.
hydrophobic	N.A.	N.A.	N.A.

*N.A. = not applicable (not relevant)

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Covalency of Atoms of Central Importance in Biological Molecules

Atom	Chemical Symbol	Covalency
Hydrogen	H	1
Oxygen	O	2
Carbon	C	4
Nitrogen	N	3
Phosphorous	P	5
Sulfur	S	2

These atoms all readily form covalent bonds. They each have essential functions in biological molecules.

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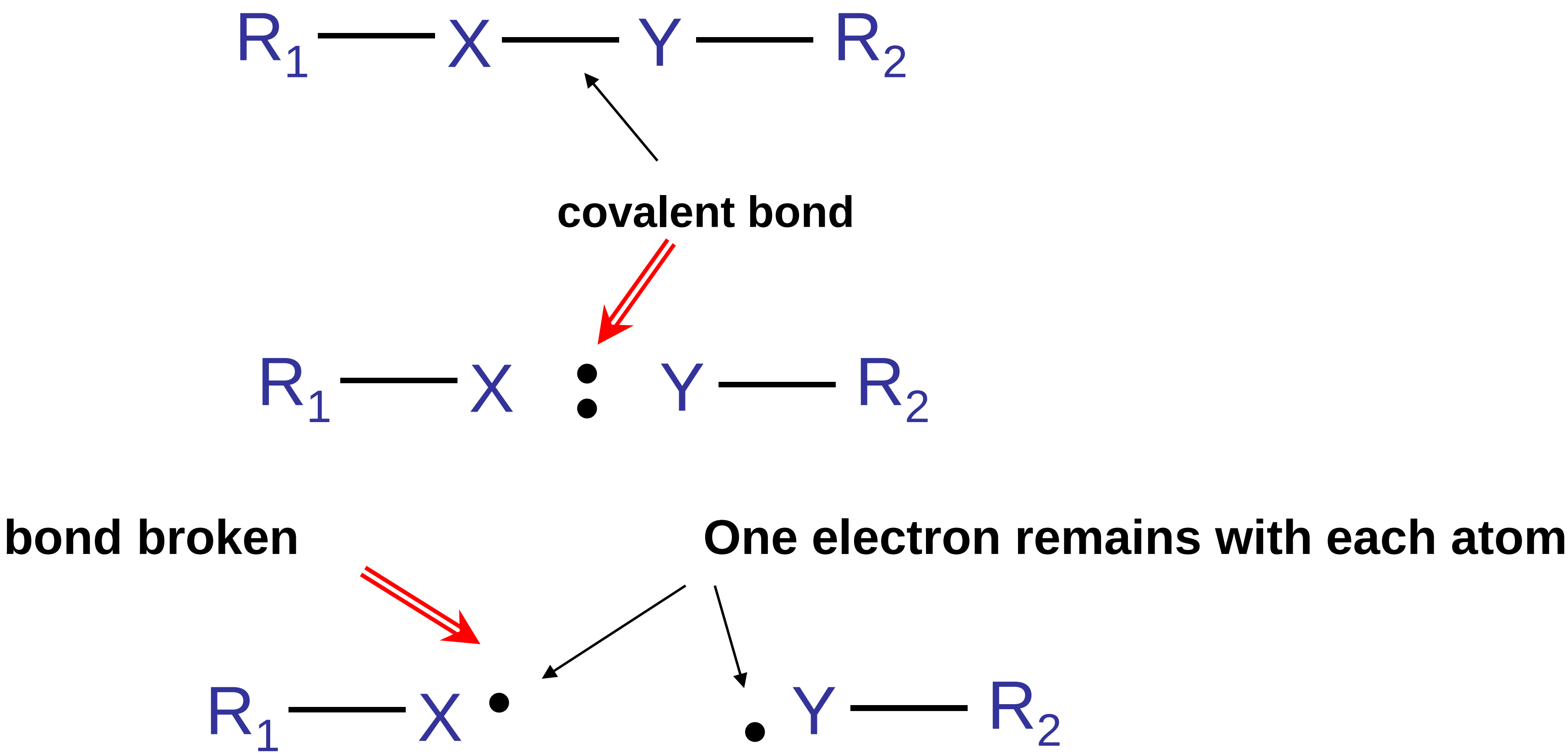
Review (from discussion periods)



The bond strength of a covalent bond may be described as the total amount of energy (measured in kilojoules, for example) required to break a specific covalent bond in each molecule of one mole of molecules.

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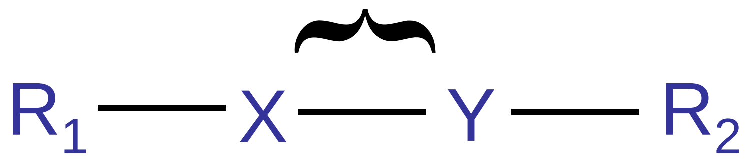
The bond length of a covalent bond is the distance (generally given in units of Å) that two covalently bonded atoms are separated from each other.



Recall that an angstrom (Å) is a unit of length equal to 1/10 of a nanometer or one ten-millionth of a millimeter.

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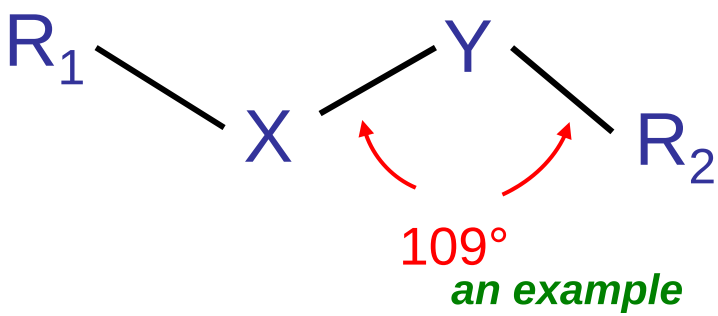
Review (from discussion periods)

Bond angles not shown accurately



Bond angles shown more accurately

The bond angle of a covalent bond is the angle formed by 2 bonds that hold 3 adjacent atoms together.

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Chemical Composition of Cells by Weight

I. Active cells are >50% water.
   Typical animal cells are 60% - 70% water.
   Many plant cells are >90% water.

II. The non-water portion of a cell is its "dry weight"
   The dry weight of cells is composed of:
   A. ~ 1% inorganic substance.
   B. ~ 99% organic molecules.

   Most organic molecules of cells fall into one of 4 four broad categories:
   1. carbohydrates,
   2. lipids,
   3. proteins,
   4. nucleotides and polynucleotides.

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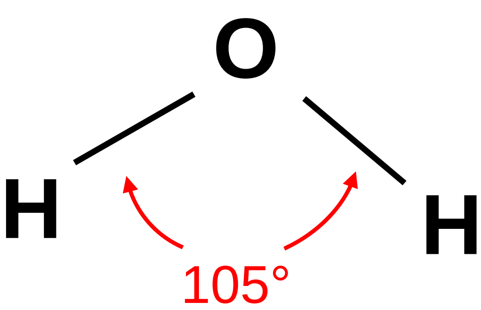
Review (from discussion periods)

Ways to Express the Formula of Water

H_2O Chemical formula

HOH or H—OH Structural formulas



Stereo formula

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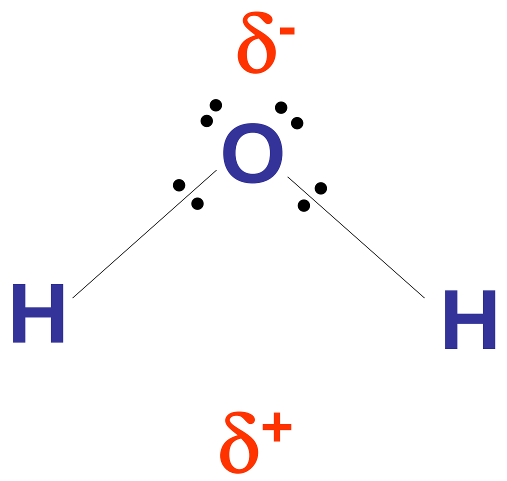
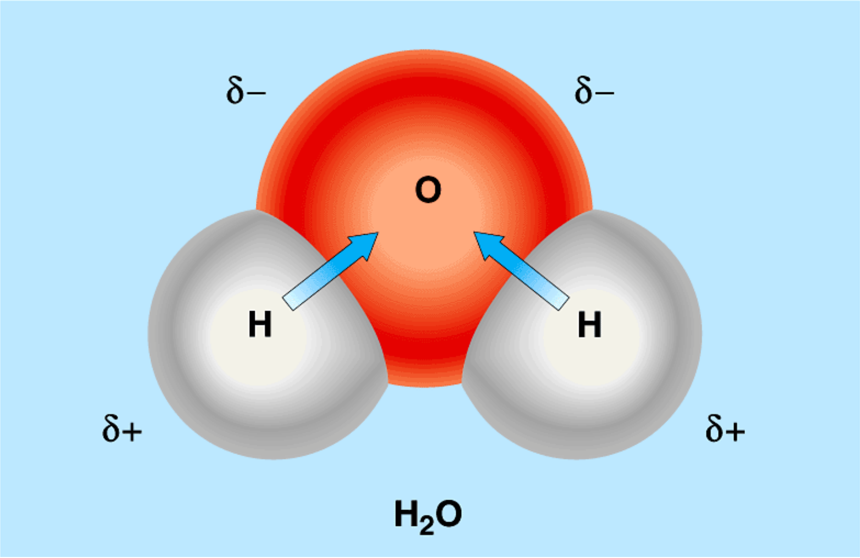
Review (from discussion periods)

Polarity of Water





Water is a polar molecule because:

1. it's bond angle isn't 180º, making the molecule asymmetrical,

2. its oxygen atom is much more electronegative than the hydrogen atoms so it's covalent bonds are <u>polar</u> <u>covalent</u> <u>bonds</u>.

3. Two lone (non-bonded) pairs of electrons (negative charges) on the oxygen atom project away from the hydrogen atoms.

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Both O and N are very electronegative in comparison to H, C, P and S.

Atom	Chemical Symbol	Covalency	Electronegative
Hydrogen	H	1	
Oxygen	O	2	✓ ✓
Carbon	C	4	
Nitrogen	N	3	✓
Phosphorous	P	5	
Sulfur	S	2	

O and N form polar covalent bonds when bonded to H, C, S or P.

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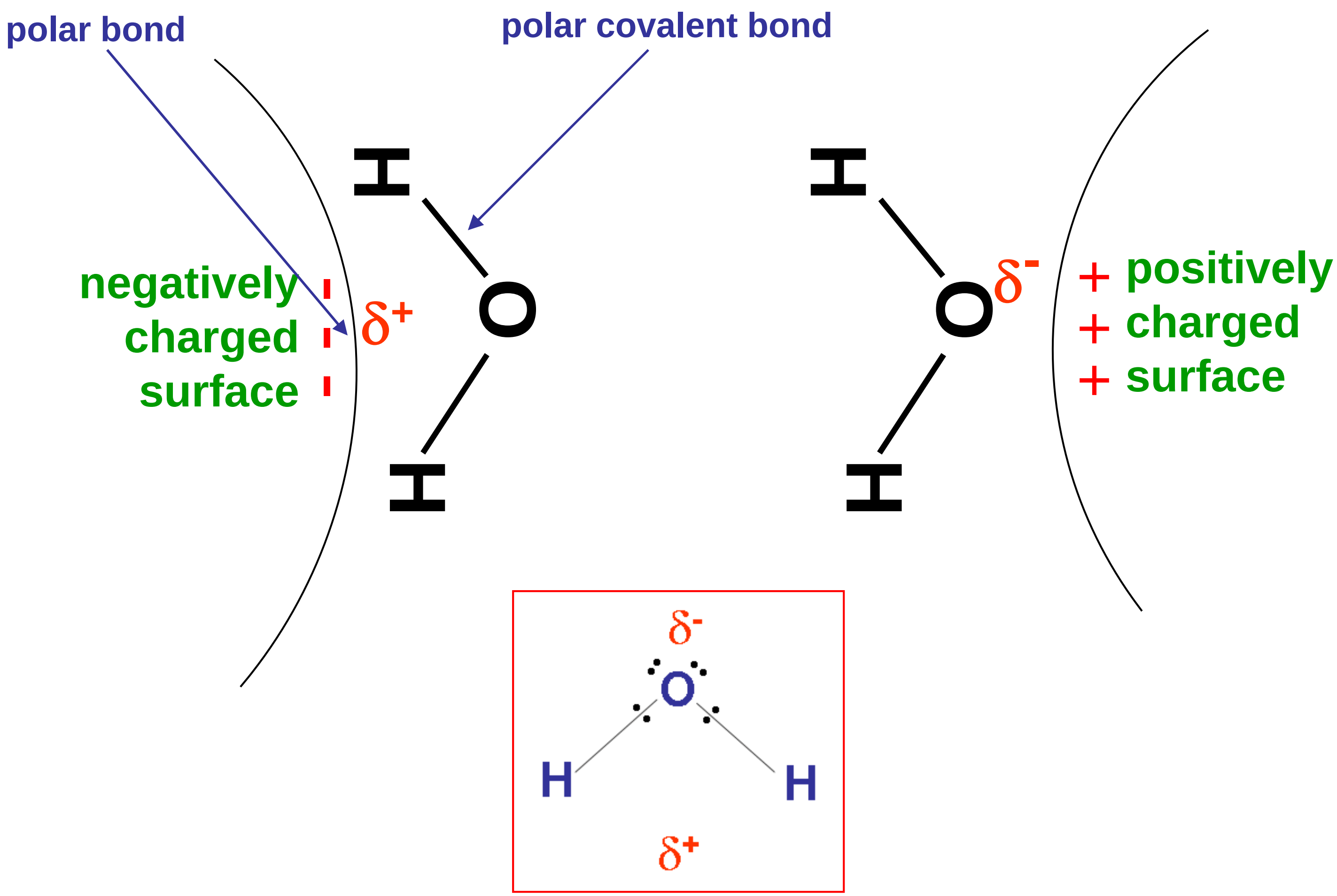
Polar Bonding of Water



Be sure to know the difference between a <u>polar covalent</u> bond and a <u>polar</u> bond.

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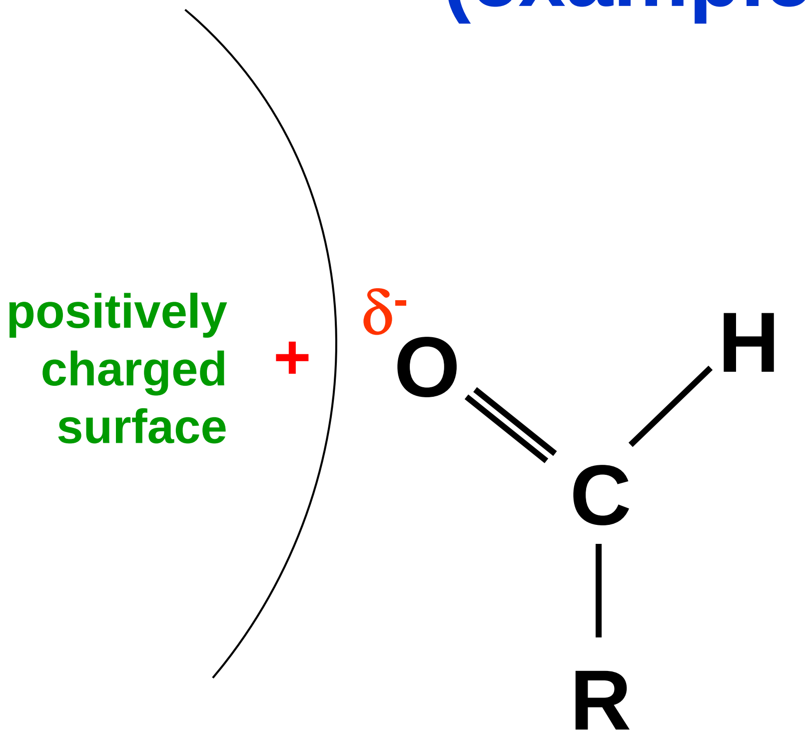
Polar Bonding
(example aldehyde)



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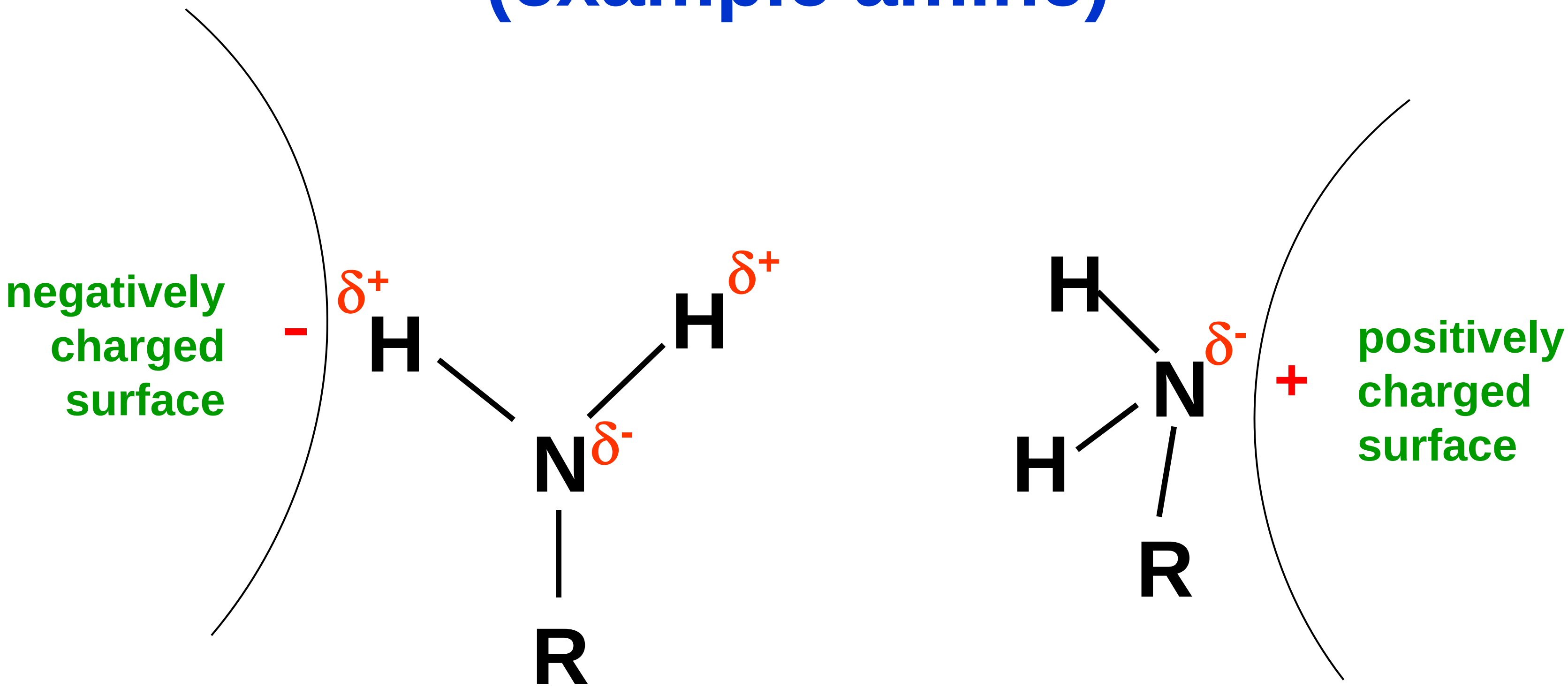
Polar Bonding (example amine)



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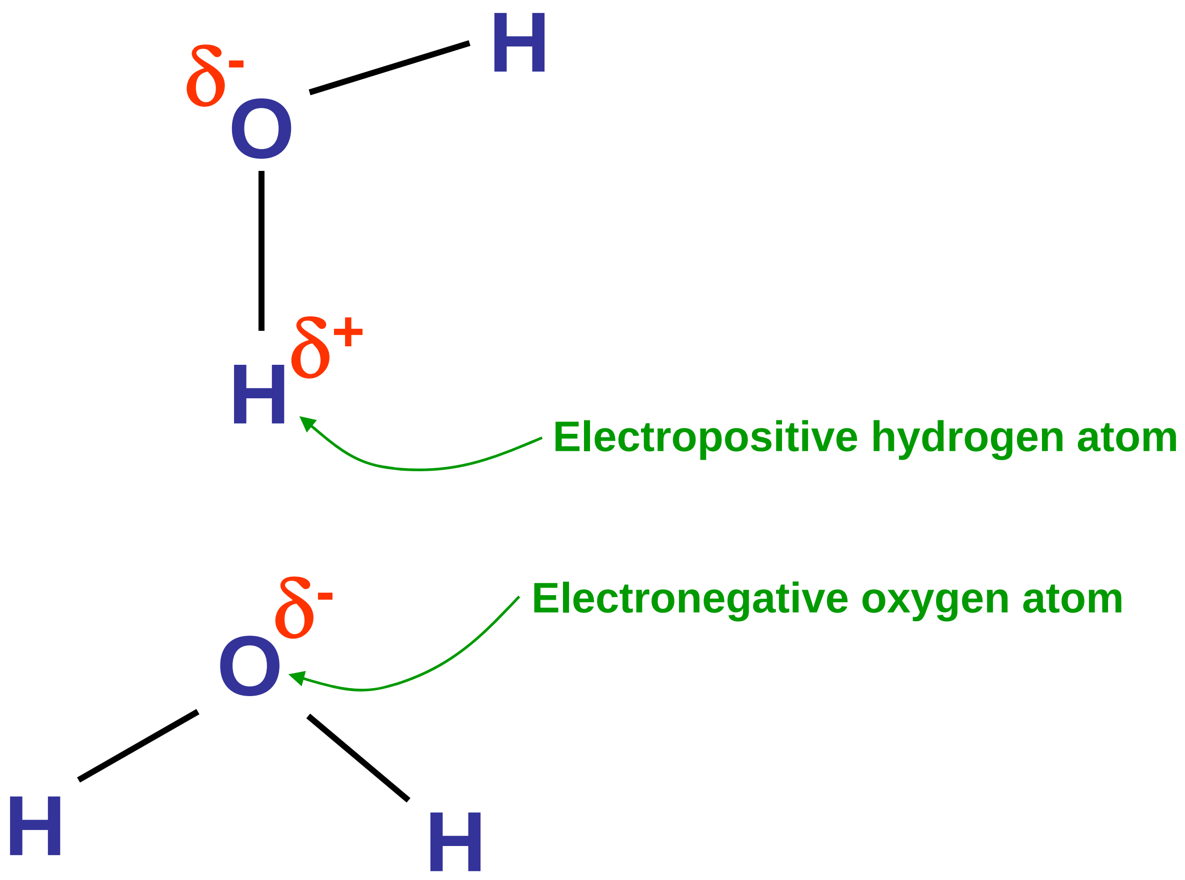
Review (from discussion periods)

Polar Attraction Between two Water Molecules



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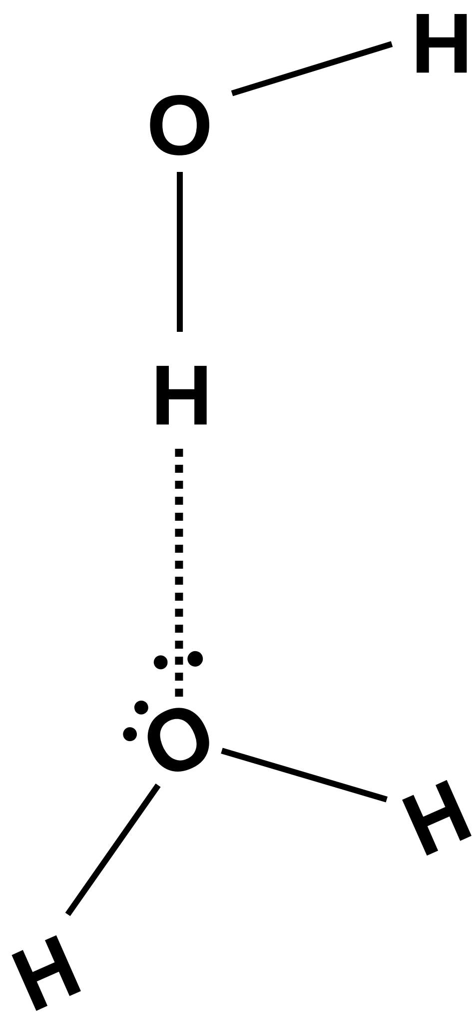
Hydrogen Bond Between Two Water Molecules



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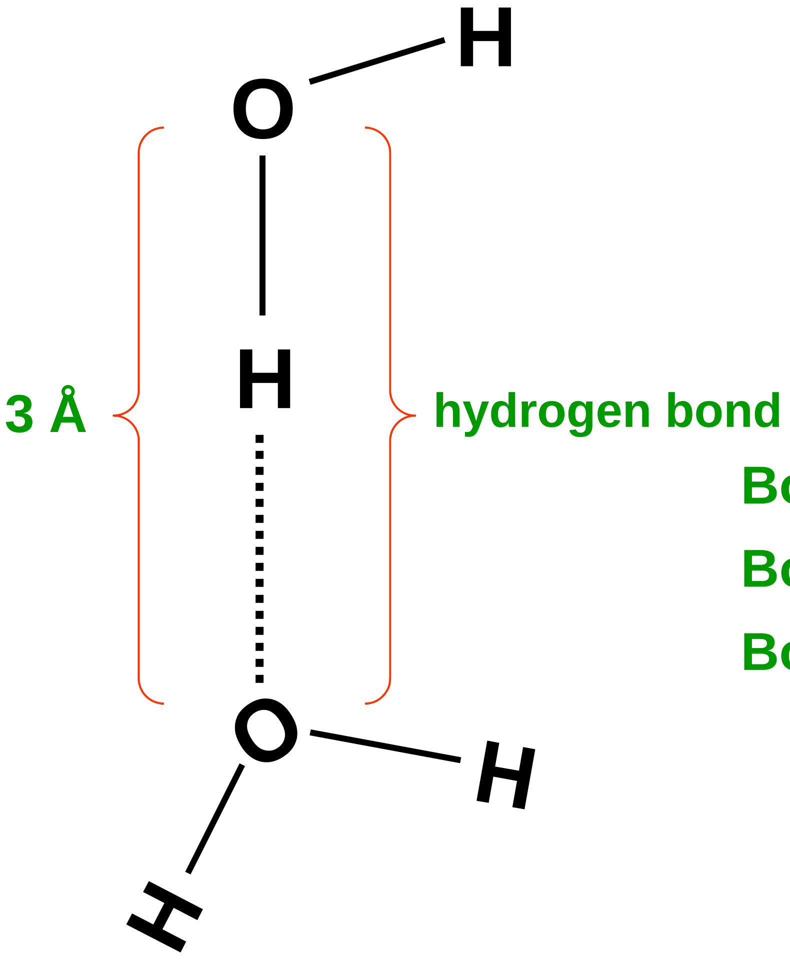
Review (from discussion periods)

Bond Characteristics of a Hydrogen Bond Between Two Water Molecules



Bond length: ~ 3 Å

Bond angle: 180°

Bond strength: ~ 30 - 40 KJ/mole

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Description of a Hydrogen Bond

A hydrogen bond may form within a molecule or between two molecules when a hydrogen atom that is covalently bonded to an oxygen atom or a nitrogen atom approaches another oxygen or nitrogen atom.

The hydrogen atom comes to lie approximately midway between the two electronegative atoms, and is bonded to both.

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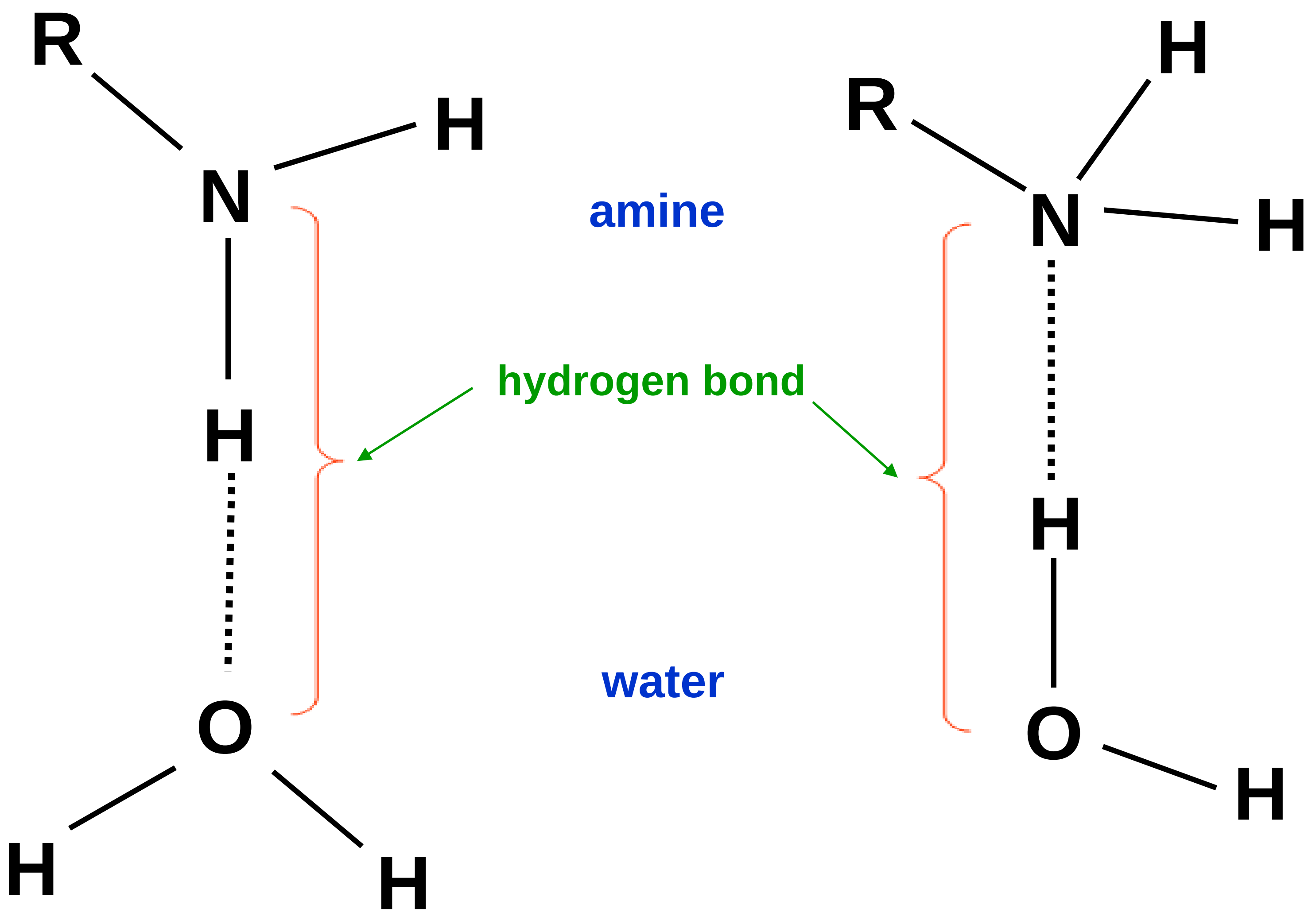
Two ways that Hydrogen Bonding Can Occur Between a Water Molecule and an Amine



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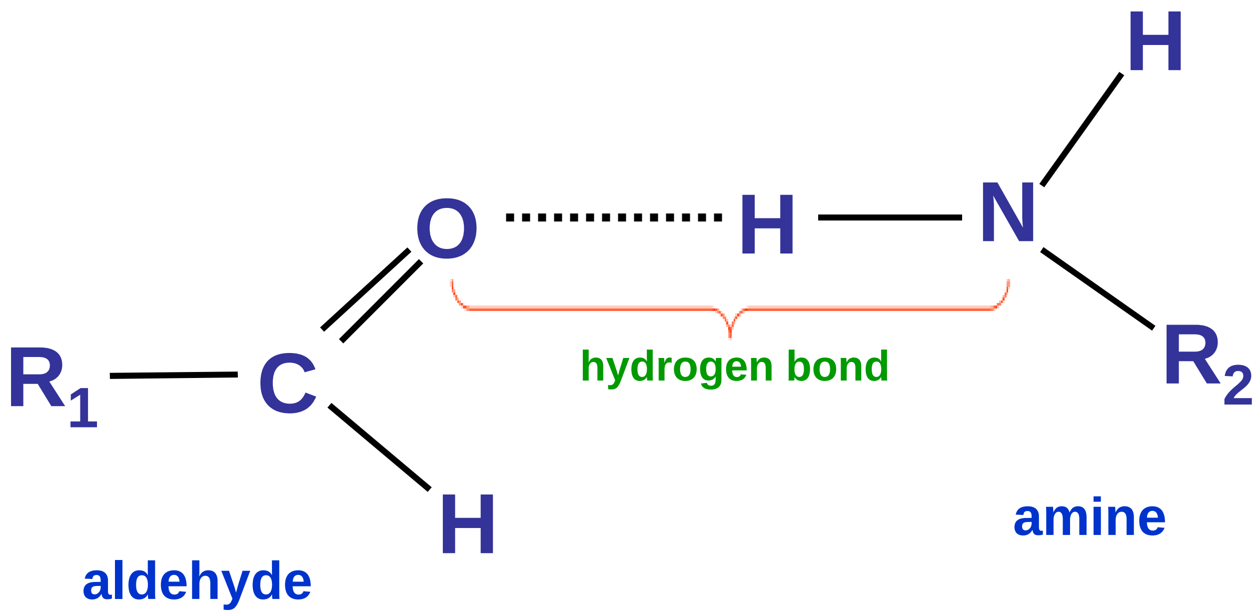
Hydrogen Bonding Between an Aldehyde and an Amine



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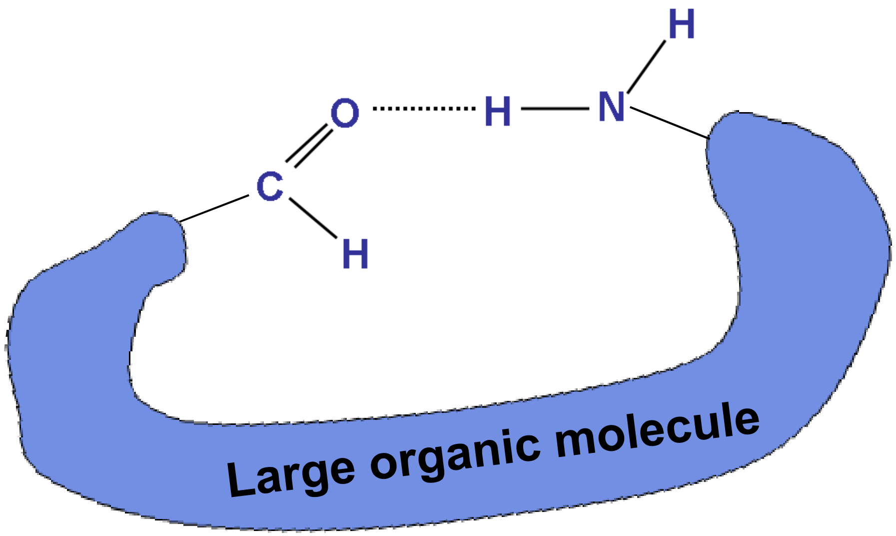
An Intramolecular Hydrogen Bond



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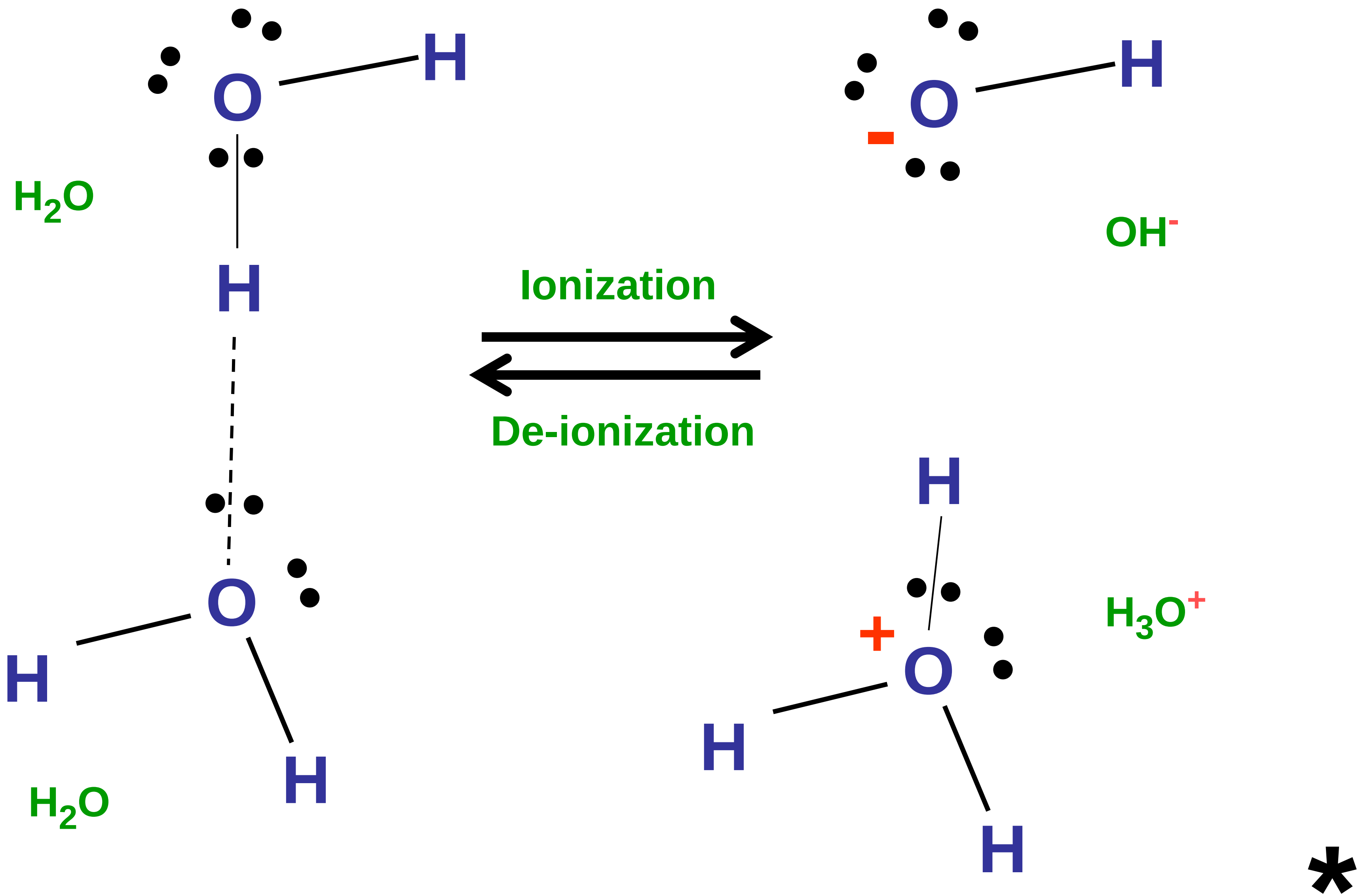
Reversible Ionization of Water



Reversible Ionization of Water Shown as a Chemical Reaction

$$H_2O + H_2O \underset{\text{De-ionization}}{\overset{\text{Ionization}}{\rightleftharpoons}} H_3O^{+} + OH^{-}$$

or

$$2\,H_2O \rightleftharpoons H_3O^{+} + OH^{-}$$

At any instant of time in pure water at room temperature, approximately one molecule in 300 million is in the ionized form. The longest arrow shown in the reverse reaction indicates that the reaction prefers to go in the reverse reaction, and therefore at any instant of time most water molecules are in the non-ionized form.

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In pure water at room temperature:

$[H_3O^+] = 10^{-7}$ M

pH = 7

Brackets around a chemical structure are read as "concentration of".

Def: $pH = -\log_{10}[H_3O^+]$

Also in pure water, $[OH^-] = 10^{-7}$ M

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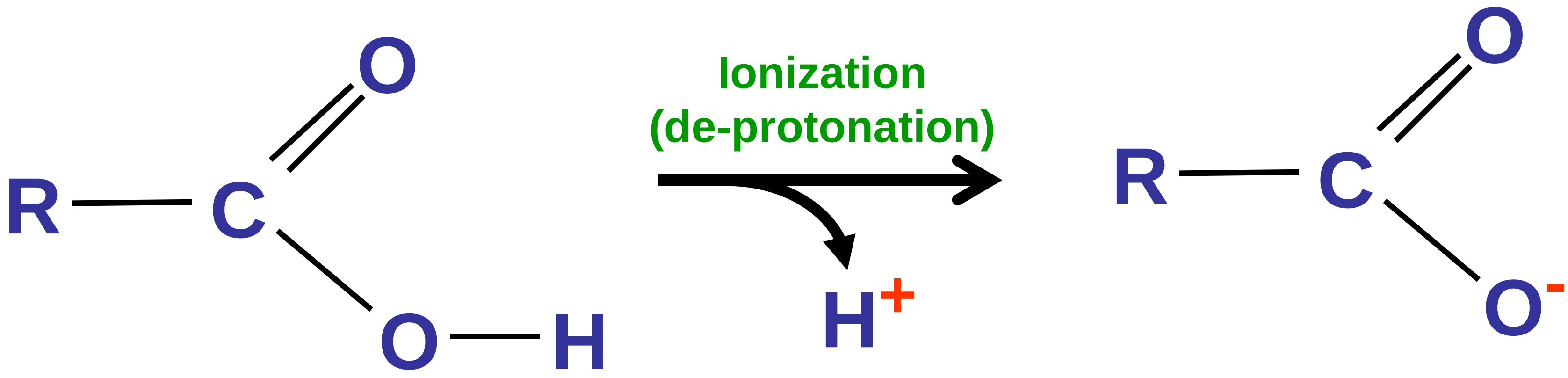
Ionization of Carboxylic acids



But de-protonation cannot occur unless there is another molecule nearby that can simultaneously accept the proton (become protonated).

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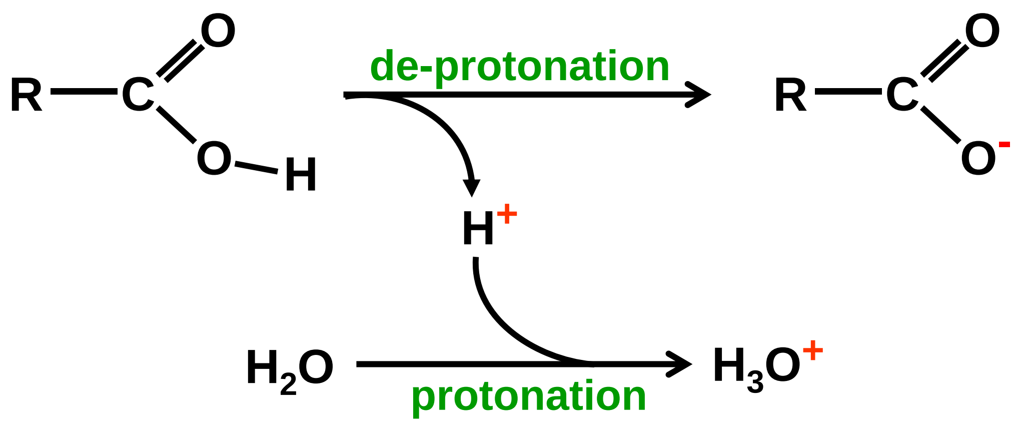
De-protonation of a Carboxylic Acid in Water



net reaction (reversible):

$$R{-}COOH + H_2O \rightleftharpoons R{-}COO^- + H_3O^+$$

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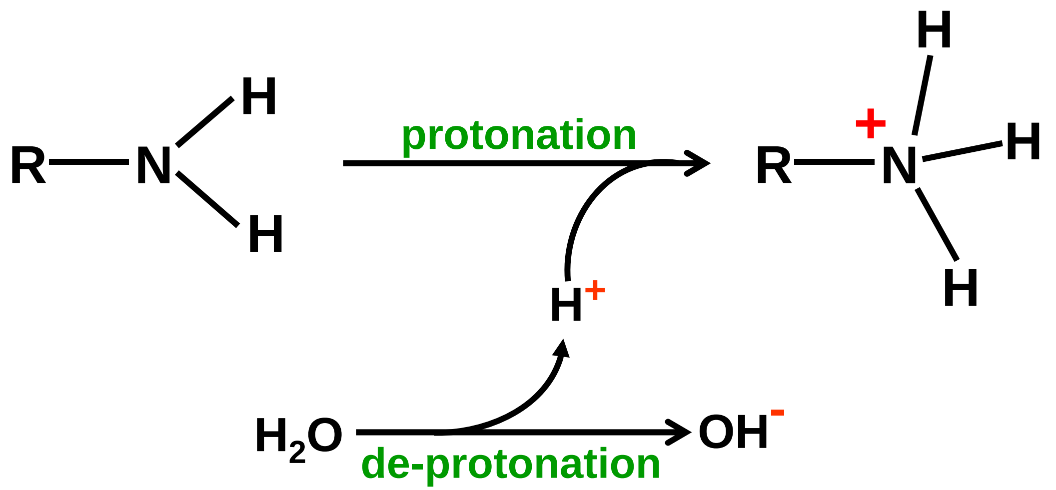
Protonation of an Amine in Water



net reaction (reversible):

$$R{-}NH_2 + H_2O \rightleftharpoons R{-}NH_3^{+} + OH^{-}$$

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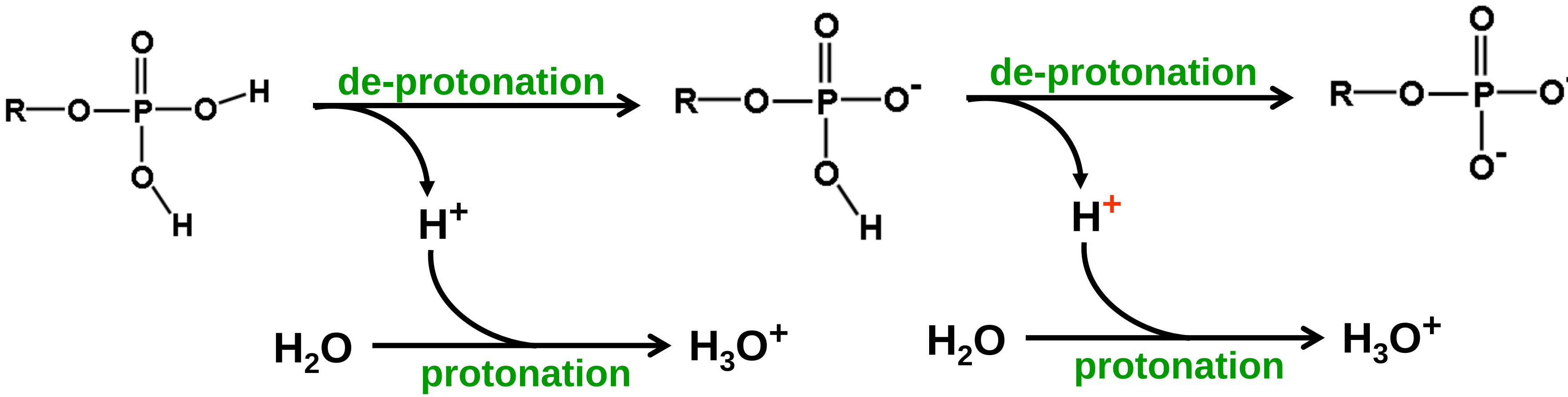
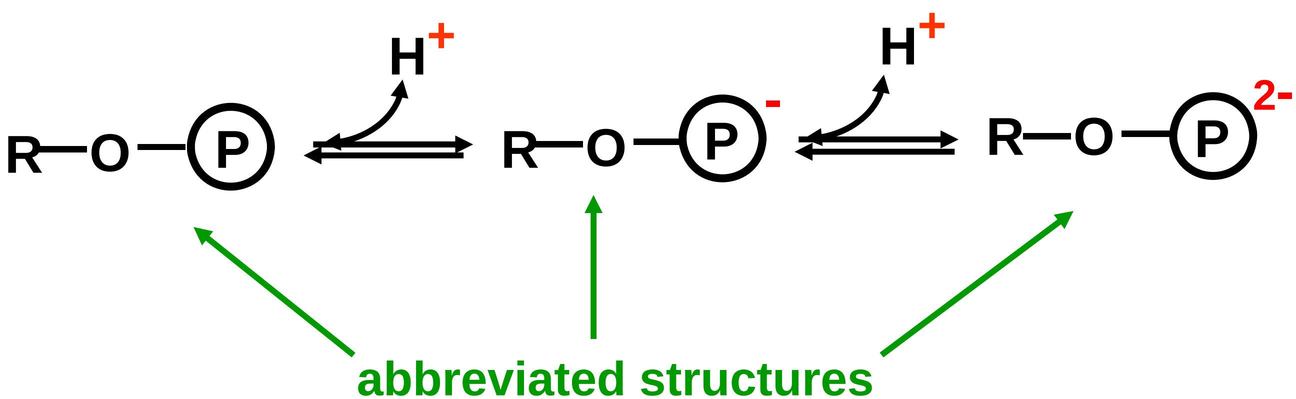
De-protonation of Phosphoric acid in Water



net reaction (reversible):



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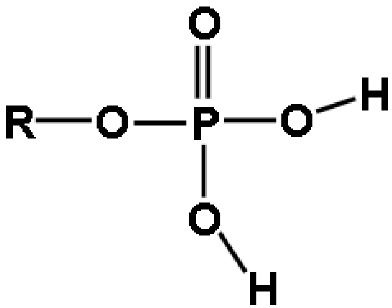
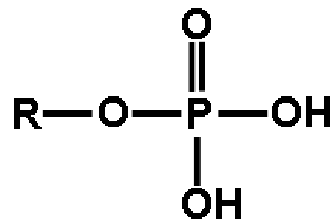
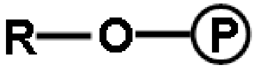
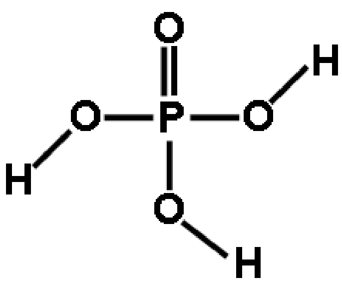
The following abbreviations for phosphoric acids are often used in cell and molecular biology.

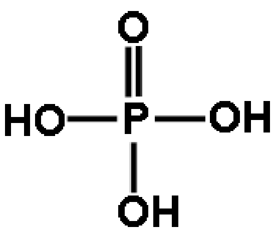






organic phosphoric acid





H_3PO_4

P_i

inorganic phosphphoric acid

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