CHAP TER 1 STRUCTURE AND BONDING:

Octet Rule: Atoms strive to attain (a complete outer shell of) 8 valence electrons
- H “wants” 2 e⁻
- Second-row elements “want” 8 e⁻
- Notable Exceptions to the Octet Rule:
  - Be “wants” 4 e⁻
  - B “wants” 6 e⁻
  - S “wants” 10 or 12 e⁻
  - P “wants” 10 e⁻

Guide to Drawing Lewis Structures:

Step 1: Arrange atoms next to each other that you think are bonded together
Ex: CH₃CH₂O

Step 2:
- Count # of valence e⁻ from all atoms
  - Add one e⁻ for each (-) charge
  - Subtract one e⁻ for each (+) charge
  - The sum gives you total # of e⁻ that must be used to draw the structure
Ex:

Here we've drawn it as written in the condensed structure. But notice the H is going to get more than 2 e⁻ which we don't want. Also, when we go to assign lone pairs later, the O will have a (-) charge which is not shown in the structure we've been given.
Step 3: Arrange electrons around atoms
- Place bond between every two atoms
  - H gets 2 e⁻
  - Any second-row element gets no more than 8 e⁻
  - Use remaining e⁻ to fill octets with lone pairs
  - If all valence electrons are used and atom doesn’t have an octet, form multiple bonds

Ex:

We made 8 single bonds which accounts for 8(2) = 16 e⁻'s. Now give remaining e⁻'s, in the form of lone pairs, to O which doesn't yet have an octet.

2 lone pairs, is 4 e⁻'s. We've successfully used all valence e⁻'s, and all our atoms(excluding H which gets 2 e⁻'s) have an octet.

Step 4: Assign formal charges to atoms (when asked)

Formal charge = # of valence electrons - # of electrons an atoms owns

- An atom owns all its unshared electrons(any lone pairs) and half of its shared electrons(from bonds)

# of electrons an atoms owned =

# of unshared electrons + ½ [# of shared electrons]

Resonance Structures: two Lewis structures having the same arrangement of atoms but a different arrangement of electrons.
- A single molecule does not actually exist as each of its individual resonance structures
  - It exists as the resonance hybrid

Determining Major and Minor Resonance Contributors:
A ‘better’ resonance structure is one that is more stable. The ‘better’ the resonance structure, the larger its contribution to the hybrid. Use the following rules to determine which resonance structure is a larger contributor to the resonance hybrid (in order of importance):

1. Resonance structures w/ more bonds and fewer charges are more stable
2. Resonance structures in which every atom has a full octet are more stable
3. Resonance structures that put a (-) charge on the more electronegative atom are more stable

**NOTE:** It’s okay for carbon to have an incomplete octet in a resonance structure, but O, N, or any halogen should always have a full octet.

**Bond LENGTH and STRENGTH trends:**

- Bond length is primarily affected by the electrostatic attraction between (+) nuclei and (-) electrons of an atom.
  - The stronger the attraction, the shorter the bond length
- Bond length decreases going left to right across a row and increases down a column

```
C-H > N-H > O-H
 Increasing bond length
```

```
H-F < H-Cl < H-Br
 Increasing bond length
```

- Bond length decreases as the number of electrons between two nuclei increases (i.e. Bond length decreases as bond order increases)

```
CH₃–CH₃ < CH₂=CH₂ < H≡C≡C–H
 Increasing bond length
```

- Bond length decreases as percent s-character increases
  - s-orbital holds electrons more tightly, so greater s-character, shorter bond

```
Cₛᵖ–H < Cₛᵖ²–H < Cₛᵖ³–H
 Increasing bond length
```

- Bond strength is inversely related to bond length. Shorter bonds are stronger bonds

```
longest C–C bond weakest bond — C—C — C≡C — shortest C–C bond strongest bond
 Increasing bond strength
```
CHAPTER 2 **ACIDS AND BASES:**

**Acid & Base Definition(s):**
- Bronsted-Lowry:
  - Acid: proton donor
  - Base: proton acceptor
- Lewis:
  - Acid: electron pair acceptor (electrophile)
  - Base: electron pair donor (nucleophile)

**Conjugate Acid-Base Pair Relationship:**
- Conjugate acid base pair: An acid and base that differ only in the presence of a proton
- Strong acids have weak conjugate bases (and vice versa)

**Equilibrium:**
- @ equilibrium weaker acid and base are favored
  - **Why?** They’re the most stable species
- Determine the direction of equilibrium (reactants or products favored) by finding weaker acid/base
  - Estimate approx. ratio of reactants to products by:
    - Taking $pK_a$ difference, $x$, rounded to whole number of acids

---

**Approximate $pK_a$ values (rounded to nearest 5)**

<table>
<thead>
<tr>
<th>&lt;0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>25</th>
<th>35</th>
<th>45</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{H}^+\text{O}^-$</td>
<td>$\text{RCH}_2\text{O}$</td>
<td>$\text{NH}_4^+$</td>
<td>$\text{ROH}$</td>
<td>$\text{RC}≡\text{CH}$</td>
<td>$\text{NH}_3$</td>
<td>$\text{R}_2\text{C}≡\text{CH}$</td>
<td>$\text{CH}_4$</td>
</tr>
<tr>
<td>$\text{H}^+\text{R}$</td>
<td>$\text{NH}_3$</td>
<td>$\text{R}_2\text{NH}_2$</td>
<td>$\text{H}_2\text{O}$</td>
<td>$\text{R}_{\text{CH}_3}$</td>
<td>$\text{R}_2\text{NH}$</td>
<td>$\text{R}_3\text{NH}$</td>
<td>$\text{R}_{\text{CH}_3}$</td>
</tr>
</tbody>
</table>
- 1:10^x if products are favored
- 10^x:1 if reactants are favored

- Is my base strong enough to deprotonate a given acid?
  - An acid can be deprotonated by the conj. Base of any acid w/ higher pKa (difference >2)

**Structure and Relative Acidity:**

**KEY CONCEPT:** Stability of the conjugate base makes more for a stronger acid

- **Element Effects:**
  - Acidity increases across a period
    - More electronegative A → more stable A^-
  - Acidity increases down a group
    - Larger A → charge is spread out over larger volume

- **Inductive Effects:**
  - Electronegative atoms withdraw e- density and stabilize conj. Base
    - The more electronegative and/or the closer it is to the (-) charge, the greater the effect

- **Resonance Effects:**
  - Resonance allows for delocalization of e-’s, making the conj. base more stable
    - The more resonance structures and/or the better the ‘quality’ of contributing resonance structures, the more stable the base

- **Hybridization Effects:**
  - More s-character means more electronegative
    - e-‘s are closer to the nucleus and lower energy
CHAPTER 4 ALKANES:

IUPAC Nomenclature:

NAMING ACYCLIC ALKANES:

**Step 1:** Find the longest continuous carbon chain, and form the parent name (how many C’s) and suffix (-ane for alkane).

**Step 2:** Number the carbons in the chain to give the FIRST substituent the LOWER number.

**Step 3:** Name and number the substituents.
- if two or more identical substituents are bonded to the longest chain, use prefixes to indicate how many (di- = 2, tri- = 3, tetra- = 4, etc.)

**Step 4:** Combine substituent names and numbers + parent + suffix.
- alphabetize the names of the substituents and precede the name of each substituent by the number that indicates its location
  - NOTE: no need to know iso, sec-, and tert- prefixes

Newman Projections:

Newman projections are end-on representations for conformations that show the three groups bonded to each carbon atom in a particular C-C bond.
- in the eclipsed conformation, the bonds on one carbon are directly aligned with the bonds on the adjacent carbon
- in the **staggered** conformation, the bonds on one carbon bisect the bond angles on the adjacent carbon

A staggered conformation with two similar groups 180° from each other is called **anti**. A staggered conformation with two similar groups 60° from each other is called **gauche**.

Staggered conformations are more stable than eclipsed conformations, and anti conformations are more stable than gauche conformations due to less **steric strain** exhibited between atoms.

**DRAWING NEWMAN PROJECTIONS:**

**Step 1:** Looking directly down a C-C bond, draw a circle with three lines meeting at the center of the circle and three lines coming out of the edge of the circle.

- the point where the three lines meet at the center represents the FRONT carbon and the circle itself represents the BACK carbon

**Step 2:** Add the atoms on each bond.

- atoms on straight lines go on the middle line
- atoms on solid wedges go on the line pointing to the right
- atoms on dashed wedges go on the line pointing to the left
Chair Conformations:

In cyclohexanes, up carbons and down carbons alternate around the ring.

axial atoms (blue) are located above and below the ring (along a perpendicular axis)
- equatorial atoms (red) are located in the plane of the ring (around the equator)
- on an UP carbon, the axial atom is UP and the equatorial atom is DOWN
- on a DOWN carbon, the axial atom is DOWN and the equatorial atom is UP

RING-FLIPPING:
When flipping the ring of a cyclohexane, the UP carbons become DOWN carbons and the DOWN carbons become UP carbons. Axial and equatorial atoms are interconverted during a ring flip.

In substituted cyclohexanes, two conformations are not equally stable:

- **A**, which places the larger methyl group in the roomier equatorial position, is considerably more stable than **B**, which places it axial
- with a large equatorial group, steric interactions with nearby groups are minimized
- with a large axial group, destabilizing steric interactions occur between nearby groups

**DRAWING CONFORMATIONS FOR SUBSTITUTED CYCLOHEXANES**

**Step 1:** From the skeletal structure, draw one chair form and add the substituents.
- if there is stereochemistry, atoms on solid wedges point UP (above the ring) and atoms on dashed wedges point DOWN (below the ring)
**Step 2:** Ring-flip the cyclohexane ring and convert UP carbons to DOWN carbons and vice versa.

**Step 3:** Add the substituents to the second conformation.
- ring-flipping converts axial bonds to equatorial bonds and vice versa
CHAPTER 5 STEREOCHEMISTRY:

Stereogenic (Chiral) Center: A carbon atom bonded to four different groups

5.1 Assigning (R) and (S) configuration:

1. Assign priority to 4 groups directly bonded to stereogenic center
   a. Based off atomic number (highest atomic # gets highest priority)
   b. If two atoms bonded to center are the same, continue along a chain until point of difference
   c. Atom(s) part of a multiple bond count as eq. number of single bonds (double bond = 2 single bonds)

Ex(5.1.1): Breaking the Tie

2. Orient the lowest priority group(4) back on a dashed wedge
   a. With group 4 facing away, trace a circle from 1→2→3
      i. Clockwise: (R)
      ii. Counterclockwise: (S)

Ex(5.1.2): Three Cases

1. On a dashed-wedge  2. On a solid-wedge  3. In the plane
5.2 Chirality and Stereoisomers:

Symmetry definition(s):
- **Achiral**: superimposable on its mirror image
  - Look for plane of symmetry
- **Chiral**: not superimposable on its mirror image
- **Identical**:
  - Mirror image produces exact same molecule
- **Enantiomers**:
  - Stereoisomers that are non-superimposable mirror images
- **Diastereomers**:
  - Stereoisomers that are not mirror images

This molecule is chiral. We can identify that 2 ways:

1. We have a carbon bonded to 4 unique groups (F, I, methyl, ethyl), so we have exactly one stereogenic center → chiral
2. If we draw the mirror image of the left molecule, we get the right one. But we cannot superimpose the left onto the right (or vice versa). Therefore as a non-superimposable molecule, it is chiral

**Note**: Because this molecule has exactly one stereogenic center, we not only know that it is chiral, but also it is enantiomers with its mirror image.

Using stereogenic centers to define chirality:
- 0 stereogenic centers → **achiral** *(few exceptions)*
- 1 stereogenic center → **always chiral**
- 2 or more stereogenic centers → **may be achiral or chiral**
- **Identical**:
- Same (R) and (S) designations
- **Enantiomers:**
  - Exactly opposite (R) and (S) designations
- **Diastereomers:**
  - Same designation for (at least) one center and opposite for (at least) one other center

**Meso Compound:** achiral molecule w/ stereogenic center(s)
II. Kinds of Organic Reactions

Substitution

- Reaction where one atom or group of atoms is replaced by another atom or group of atoms

\[
\text{H} \cdot \cdot \cdot \text{C} \cdot \cdot \cdot \text{H} + \text{Cl} - \text{Cl} \xrightarrow{\text{hv}} \text{H} \cdot \cdot \cdot \text{C} - \text{Cl} + \text{H} - \text{Cl}
\]

Elimination

- Some parts of the reactant are lost and a pi bond is formed
- The elements that are lost are replaced by the formation of a pi bond

\[
\begin{align*}
\text{Br} & \quad \xrightarrow{\text{H}_2\text{O}} \\
\text{Cyclohexane} & \quad \text{Cyclohexene}
\end{align*}
\]

Addition

- The addition of elements to a starting material

\[
\text{H} \cdot \cdot \cdot \text{C} - \text{C} \cdot \cdot \cdot \text{H} + \text{Cl} - \text{Cl} \rightarrow \text{H} - \text{C} - \text{C} - \text{H} \]

\[
\text{H} \cdot \cdot \cdot \text{C} \cdot \cdot \cdot \text{H} \quad \text{Cl} \quad \text{Cl}
\]
III. Reaction Mechanism

- **Concerted reactions**
  - One step reactions known as *concerted* reactions
  - Bonds are made and broken in one step
  - No reactive intermediates

- **Stepwise Reactions**
  - Reactions with more than one step
  - The starting material will be converted into a reactive intermediate

IV. Bond Dissociation Energy

- Energy needed to homolytically cleave a covalent bond
- Energy absorbed or released in a reaction = $\Delta H^\circ$
- $(+) \Delta H^\circ =$ endothermic absorb energy; $(-) \Delta H^\circ =$ exothermic release energy
- Bond dissociation energy for a given atom constant (ex. H-C; H-N; H-O) *increases* as you go down a row and *decreases* as you move down a column.

**Enthalpy of Reaction $\Delta H^\circ$**

- To calculate the enthalpy of reaction, look first at bonds formed and broken
- Sum up bond dissociation energy for all bonds broken (+) that is an endothermic process
- Sum up all bond dissociation energies for bonds formed (-) that is an exothermic process
- Add these two values together

b. $\text{CH}_3\text{OH} + \text{HBr} \rightarrow \text{CH}_3\text{Br} + \text{H}_2\text{O}$

<table>
<thead>
<tr>
<th>Bonds broken</th>
<th>$\Delta H^\circ$ (kJ/mol)</th>
<th>Bonds formed</th>
<th>$\Delta H^\circ$ (kJ/mol)</th>
<th>Overall $\Delta H^\circ$ =</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH$_3$–OH</td>
<td>+ 389</td>
<td>CH$_2$–Br</td>
<td>– 293</td>
<td>+ 757 kJ/mol</td>
</tr>
<tr>
<td>H–Br</td>
<td>+ 368</td>
<td>H–OH</td>
<td>– 498</td>
<td>– 791 kJ/mol</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>+ 757 kJ/mol</td>
<td><strong>Total</strong></td>
<td><strong>– 791 kJ/mol</strong></td>
<td><strong>ANSWER:</strong> – 34 kJ/mol</td>
</tr>
</tbody>
</table>
IV. Thermodynamics & Kinetics

\( K_{eq} \)
- Constant of equilibrium value that expresses which materials dominate for a rxn once equilibrium is reached
- Calculate = \([\text{Products}] / [\text{Reactants}]\)
- If greater than 1 products favored; If less than 1 reactants favored
- "More stable compounds will be favored at equilibrium"
- \( \Delta G^\circ \), Gibbs Free Energy, is related to \( K_{eq} \) in an inverse relationship; when (+) \( K_{eq} \) less than 0, when (-) \( K_{eq} \) greater than 0.

Energy Diagrams
- Shows energy changes through a reaction as it progresses; with number of steps, reagents involved, and energies of products, reactants, and intermediates shown
- Reactive intermediates are formed by a reaction and found within a step and then react so that they are not a final product of the reaction

Energy Difference
- Overall energy difference between reactants & products is \( \Delta H^\circ \) - if positive, reaction favored and exothermic; if negative, reaction absorbs energy and is endothermic

Transition state
- unstable maximum state of energy that must be reached where bonds are partially broken from the reactants and bonds are partially formed for the product
- At this point, products can be formed or starting material can be regenerated

Activation Energy
- Energy barrier between transition state and starting material energy is \( E_A \)
- This value can be lowered with a catalyst: NOTE - this DOES NOT affect \( \Delta H^\circ \) and exothermic/endothermic nature; rather, it only acts to reduce the energy barrier and affects the reaction rate
RDS

- Rate-determining step is the slowest step in the reaction and is the step with the transition state of highest free energy

Constant of equilibrium value that expresses which materials dominate for a rxn once equilibrium is reached

Calculate = [Products]/[Reactants]

If greater than 1 products favored; If less than 1 reactants favored

*More stable compounds will be favored at equilibrium*

\( \Delta G^\circ \), Gibbs Free Energy, is related to \( K_{eq} \) in an inverse relationship; when (+) \( K_{eq} \) less than 0, when (-) \( K_{eq} \) greater than 0.
**IR SPECTROSCOPY:**

- different kinds of bonds vibrate at different frequencies, so they absorb different frequencies of IR light
- IR spectroscopy distinguishes between the different kinds of bonds in a molecule, so it is possible to determine the functional groups present

**CHARACTERISTICS OF AN IR SPECTRUM**

IR spectrum of propan-1-ol (CH₃CH₂CH₂OH):

- each peak corresponds to a particular kind of bond, and each bond type (such as O-H and C-H) occurs at a characteristic frequency
- wavenumber and frequency decreases from left to right
- the **functional group region** occurs at ≥ 1500 cm⁻¹
  - common functional groups give one or two peaks in this region, at a characteristic frequency
- **NOTE:** no need to know fingerprint region
IR TRENDS:

- IR absorption depends on **bond strength** and **atom mass**
  - **bond strength**: stronger bonds vibrate at higher frequency
  - **atom mass**: bonds with lighter atoms vibrate at higher frequency

![Diagram showing increasing wavenumber and energy with bonds to hydrogen, triple bonds, double bonds, and single bonds.]

- H has so little mass that H-Z bonds vibrate at high frequencies
- bond strength decreases in going from C≡C → C=C → C-C, so the frequency of vibration decreases

![Diagram showing increasing percent s-character with increasing frequency]

- the higher the percent s-character, the stronger the bond and the higher the frequency/wavenumber of absorption
SPECIFIC IR ABSORPTIONS:

**Interpretation of Infrared Spectra**

**X-H Region**
- Phenol & Alcohols: RO-H
  - 3700 - 3500 sharp
  - or 3200 - 3600 broad (H-bonded)
- Acids: \( \overset{\overset{\cdot}{\cdot}}{\overset{\cdot}{\cdot}} \)
  - 2800 - 3600 very broad
- Amines & Amides: \( \overset{\cdot}{\cdot} \overset{\cdot}{\cdot} \)
  - 3300 - 3500
  - 2 bands: \( -N-H \)
  - primary
  - 1 band: \( -N-H \)
  - secondary
- C-H Bonds:
  - \( \overset{\cdot}{\cdot} \overset{\cdot}{\cdot} \)
    - 3200 - 3300
  - \( C=C-H \)
    - 3000 - 3200
  - O-H
    - 2700 - 2900

**sp Region**
- Acetylenes: \( C=C \)
  - 2100 (weak or absent if highly symmetrical)
- Nitriles: \( C=\overset{\cdot}{\cdot} \)
  - 2200
- Carbon dioxide: \( O=C=O \)
  - 2350

**Double Bond Region**
- Alkanes: \( C=C \)
  - 1600 - 1670 weak unless conjugated
- Imines: \( C=\overset{\cdot}{\cdot} \)
  - 1600 - 1700
- Nitro: \( \overset{\cdot}{\cdot} \overset{\cdot}{\cdot} \)
  - 1350 and 1550

**Carbonyl Groups**:
- Anhydrides: \( \overset{\cdot}{\cdot} \overset{\cdot}{\cdot} \)
  - 1800 - 1840 (2 bands)
- Acid Chlorides: \( O=C-\overset{\cdot}{\cdot} \)
  - 1800
- Esters: \( \overset{\cdot}{\cdot} \overset{\cdot}{\cdot} \)
  - 1725 - 1750
- Acids: \( \overset{\cdot}{\cdot} \overset{\cdot}{\cdot} \)
  - 1710
- Amides: \( \overset{\cdot}{\cdot} \overset{\cdot}{\cdot} \)
  - 1650
- Aldehydes: \( \overset{\cdot}{\cdot} \)
  - 1725
- Carboxylate: \( \overset{\cdot}{\cdot} \overset{\cdot}{\cdot} \)
  - 1550-1610 and 1400

**Ring Contraction**:
- Add 30 for each contraction

**Conjugation**:
- Subtract 30
NMR SPECTROSCOPY:

- NMR spectroscopy is the most powerful tool for characterizing organic molecules, because it can be used to identify the carbon-hydrogen framework in a compound
  - H NMR spectroscopy is used to determine the number and type of hydrogen atoms in a molecule
  - C NMR spectroscopy is used to determine the type of carbon atoms in a molecule

H NMR SPECTROSCOPY:

- protons in different environments absorb at slightly different frequencies, so they are distinguishable by NMR

H NMR spectrum of tert-butyl methyl ether \([\text{CH}_3\text{OC(\text{CH}_3)}_3]\):

- NMR absorptions generally appear as sharp signals
- increasing chemical shift is plotted from right to left
- the terms **upfield** (to the right) and **downfield** (to the left) describe the relative location of signals
FEATURES OF A H NMR SPECTRUM:

[1] The number of signals equals the number of different types of protons in a compound

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 \\
H_a & \quad H_a \\
\text{all equivalent H's} & \quad 1 \text{ NMR signal}
\end{align*}
\]

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_2 \quad \text{Cl} \\
H_a & \quad H_b \\
2 \text{ types of H's} & \quad 2 \text{ NMR signals}
\end{align*}
\]

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_2\text{CH}_3 \\
H_a \quad H_b \quad H_c \\
3 \text{ types of H's} & \quad 3 \text{ NMR signals}
\end{align*}
\]

[2] The position of a signal (chemical shift) is determined by a proton’s electronic environment

- shielding effects shift absorption upfield; deshielding effects shifts absorption downfield
- electronegative atoms withdraw e⁻ density, deshield a nucleus, and shift an absorption downfield
  - think of Prof. King’s coat metaphor; electronegative atoms take away a nucleus’ coat (deshields) → nucleus “feels” the cold (external magnetic field B₀) more strongly → since it experiences a higher magnetic field strength, needs higher frequency to achieve resonance

\[
\begin{align*}
\text{This proton is shielded. Its absorption is upfield, 0.9–2 ppm.} & \\
\text{This proton is deshielded. Its absorption is farther downfield, 2.5–4 ppm.}
\end{align*}
\]

- loosely held \( \pi \) electrons can either shield or deshield a nucleus.
  - protons on benzene rings and double bonds are deshielded → absorb downfield
  - protons on triple bonds are shielded → absorb upfield
The intensity of a signal (or area under a signal) is proportional to the number of absorbing protons.

- if the heights of the two integrals are in a 1:3 ratio, then the ratio of absorbing protons is 1:3, or 2:6, or 3:9, and so forth
- intensity tells us the ratio, not the absolute number of protons

Spin-spin splitting occurs between nonequivalent protons on the same carbon or adjacent carbons.

Splitting Rules:
1. Equivalent protons don’t split each other’s signals.
2. A set of \( n \) nonequivalent protons on the same carbon or adjacent carbons split an NMR signal into \( n + 1 \) peaks.*
3. Splitting is observed for nonequivalent protons on the same carbon or adjacent carbons.
   - if \( H_a \) and \( H_b \) are not equivalent, splitting is observed in each of the following cases:
4. Splitting is not generally observed between protons separated by more than three σ bonds.

\[ \text{butan-2-one} \quad \text{H}_a \quad \text{H}_b \]

\[ \text{H}_a \quad \text{H}_b \text{ are separated by four } \sigma \text{ bonds.} \]

\[ \text{no splitting between } H_a \text{ and } H_b \]

\[ \text{ethyl methyl ether} \quad \text{H}_a \quad \text{H}_b \]

\[ \text{H}_a \quad \text{H}_b \text{ are separated by four } \sigma \text{ bonds.} \]

\[ \text{no splitting between } H_a \text{ and } H_b \]

5. Under usual conditions, O-H or N-H protons do not split the NMR signal of adjacent protons, and the signal due to an O-H or N-H proton is not split by adjacent protons.

*Note About Multiplets:
- multiplets usually arise when an absorbing proton has nonequivalent protons on TWO adjacent carbons
- whenever two (or three) sets of adjacent protons are equivalent to each other, use the \( n + 1 \) rule to determine the splitting pattern
  - ex. \( \text{CH}_3\text{CH}_2\text{CH}_3 \)
- when two sets of adjacent protons are different from each other (\( n \) protons on one adjacent carbon and \( m \) protons on the other), the number of peaks in an NMR signal = \( (n + 1)(m + 1) \)
  - ex. \( \text{CH}_3\text{CH}_2\text{CH}_3\text{-Br} \)
SPECIFIC H NMR ABSORPTIONS:

Protons bonded to oxygen:

- \( \text{O} - \text{C} - \text{O} - \text{H} \) ≈ 10 – 13
- \( \text{R} - \text{O} - \text{H} \) ≈ 1 – 4
  ≈ 4 – 6 in DMSO
- \( \text{Ph} - \text{O} - \text{H} \) ≈ 4 – 8
  ≈ 5 – 12 (w/ intramolecular hydrogen bond)

- \( \text{I} - \text{C} - \text{H} \) 2.2 – 4.2
- \( \text{Br} - \text{C} - \text{H} \) 2.7 – 4.2
- \( \text{Cl} - \text{C} - \text{H} \) 3.3 – 4.2
- \( \text{N} - \text{C} - \text{H} \) 2.3 – 3.0