Signature “Splitting” Patterns in $^1$H NMR Spectra

Singlet, 3H Methyl group
$\text{CH}_3\text{-}Z$
$Z = \text{non H-bearing atom; typically O, N, C of Ar, etc.}$

Singlet, 9H at ca. 1ppm
t-Butyl group $(\text{CH}_3)_2\text{C}$-

Quartet (2H) and Triplet (3H) Ethyl group
$\text{CH}_2\text{CH}_2\text{-}Z$
$Z = \text{non H-bearing atom, typically O, N, C of Ar, etc.}$

Septet (1H) and Doublet (6H) Isopropyl group
$(\text{CH}_3)_2\text{CH}$-$Z$
$Z = \text{non H-bearing atom, typically O, N, C of Ar, etc.}$

Doublet of Doublets (1H) Proton coupled to two non-equivalent protons which are attached to the same or different atoms

Two Triplets (each 2H) Adjacent methylene groups
$Z^1$-$\text{CH}_2\text{CH}_2$-$Z^2$
$Z^1, Z^2 = \text{very different non H-bearing atoms}$

Two Triplets (each 2H) and Quintet (2H) Three adjacent methylene groups
$Z^1$-$\text{CH}_2\text{CH}_2\text{CH}_2$-$Z^2$
$Z^1, Z^2 = \text{very different non H-bearing atoms}$

Figure by MIT OCW.
Spin-spin coupling in arenes:

In rigid systems, vicinal coupling can range from 0 to 15 Hz. For example:

Spin-spin coupling in alkenes:

1H NMR Coupling Constants (Expanded)

Note: Structures shown above represent generic coupling situations and not the specific molecules depicted (in which the labeled protons would be chemically equivalent and would not couple).

Figure by MIT OCW.
Spin-Spin Coupling for "Vicinal" Protons

The spin of proton $H_a$ influences the energy of the two spin states of proton $H_b$. This "coupling" is transmitted by the electrons in the bonds linking $H_a$ and $H_b$. The lowest energy state for proton $H_b$ occurs when the spins of the two protons are antiparallel. Note that this effect does not require that the molecule be in an external magnetic field.

Figure by MIT OCW.

Key Features of Spin-Spin Splitting

1. No coupling occurs among chemically (and magnetically) equivalent atoms.

2. A nucleus coupled to $n$ equivalent nuclei with spin $I$ is split into $2^nI + 1$ lines.

3. Nuclei coupled to each other have the same coupling constant ("$J$").

4. The magnitude of the coupling constant $J$ depends on the dihedral angle and type of intervening bonds, but is not affected by the strength of the applied field.

5. "First-order spectra" are obtained only if $(v_a - v_b)/J_{ab} > ca. 7$ Hz.

6. The splitting pattern for nuclei coupled to two or more nonequivalent atoms can be predicted using "tree diagrams".