

**TABLE 10.2** Characteristic Infrared Absorption Frequencies

Bond Type	Stretching, $\text{cm}^{-1}$	Bending, $\text{cm}^{-1}$
C—H alkanes	2960–2850 ( <i>s</i> )	1470–1350 ( <i>s</i> )
C—H alkenes	3080–3020 ( <i>m</i> )	1000–675 ( <i>s</i> )
C—H aromatic	3100–3000 ( <i>v</i> )	870–675 ( <i>v</i> )
C—H aldehyde	2900, 2700 ( <i>m</i> , 2 bands)	
C—H alkyne	3300 ( <i>s</i> )	
C $\equiv$ C alkyne	2260–2100 ( <i>v</i> )	
C $\equiv$ N nitrile	2260–2220 ( <i>v</i> )	
C=C alkene	1680–1620 ( <i>v</i> )	
C=C aromatic	1600–1450 ( <i>v</i> )	
C=O ketone	1725–1705 ( <i>s</i> )	
C=O aldehyde	1740–1720 ( <i>s</i> )	
C=O $\alpha,\beta$ -unsaturated ketone	1685–1665 ( <i>s</i> )	
C=O aryl ketone	1700–1680 ( <i>s</i> )	
C=O ester	1750–1735 ( <i>s</i> )	
C=O acid	1725–1700 ( <i>s</i> )	
C=O amide	1690–1650 ( <i>s</i> )	
O—H alcohols (not hydrogen bonded)	3650–3590 ( <i>v</i> )	
O—H alcohols (hydrogen bonded)	3600–3200 ( <i>s</i> , broad)	1620–1590 ( <i>v</i> )
O—H acids	3000–2500 ( <i>s</i> , broad)	1655–1510 ( <i>s</i> )
N—H amines	3500–3300 ( <i>m</i> )	
N—H amides	3500–3350 ( <i>m</i> )	
C—O alcohols, ethers, esters	1300–1000 ( <i>s</i> )	
C—N amines, alkyl	1220–1020 ( <i>w</i> )	
C—N amines, aromatic	1360–1250 ( <i>s</i> )	
NO <sub>2</sub> nitro	1560–1515 ( <i>s</i> )	
	1385–1345 ( <i>s</i> )	

*s* = strong absorption

*w* = weak absorption

*m* = medium absorption

*v* = variable absorption

**TABLE 11.1** Typical Chemical Shifts for Types of Hydrogen Atoms, Seen in Proton Magnetic Resonance Spectra

Type of Hydrogen Atom	$\delta^*$	Type of Hydrogen Atom	$\delta^*$
$\text{RCH}_3$	0.9	$\text{R}_2\text{C}=\text{CH}_2$	5.0
$\text{RCH}_2\text{R}$ acyclic	1.3	$\text{RCH}=\text{CR}_2$	5.3
cyclic	1.5	$\text{ArH}$	7.3
$\text{R}_3\text{CH}$	1.5–2.0	$\begin{array}{c} \text{O} \\    \\ \text{RCH} \end{array}$	9.7
$\text{R}_2\text{C}=\text{CCH}_3$   <b>R'</b>	1.8	$\text{RNH}_2$	1–3
$\begin{array}{c} \text{O} \\    \\ \text{RCCH}_3 \end{array}$	2.0–2.3	$\text{ArNH}_2$	3–5
$\text{ArCH}_3$	2.3	$\begin{array}{c} \text{O} \\    \\ \text{RCNHR} \end{array}$	5–9
$\text{RC}\equiv\text{CH}$	2.5	$\text{ROH}$	1–5
$\text{RNHCH}_3$	2–3	$\text{ArOH}$	4–7
$\text{RCH}_2\text{X}$ ( $\text{X} = \text{Cl}, \text{Br}, \text{I}$ )	3.5	$\begin{array}{c} \text{O} \\    \\ \text{RCOH} \end{array}$	10–13
$\text{ROCH}_3, \begin{array}{c} \text{O} \\    \\ \text{RCOCH}_3 \end{array}$	3.8		

\*The chemical shift values are given in ppm relative to tetramethylsilane at  $\delta$  0.00 and are for the hydrogen atoms shown in boldface in the formulas. The values for hydrogen atoms on oxygen and nitrogen are highly dependent on solvent, concentration, and temperature.