

# Student Honor Code

"As a student of The University of Texas at Austin, I shall abide by the core values of the University and uphold academic integrity."

(Your signature)

# PERIODIC TABLE OF THE ELEMENTS

### Elementary Subatomic Particles

| Electron                         | Proton                        | Neutron                       | Photon                        | Neutrino |
|----------------------------------|-------------------------------|-------------------------------|-------------------------------|----------|
| Symbol                           | e                             | p                             | n                             | $\nu$    |
| Rest mass (kg)                   | $9.10938291 \times 10^{-31}$  | $1.672621612 \times 10^{-27}$ | $1.674927161 \times 10^{-27}$ | 0        |
| Relative mass (amu)              | $5.485799091 \times 10^{-4}$  | $1.007276467 \times 10^{-3}$  | $1.008664916 \times 10^{-3}$  | 0        |
| Particle-antiparticle mass ratio | 1                             | 1836.15270137                 | 1836.68986104                 | 0        |
| Particle-antiparticle mass ratio | 5.485799091                   | 0.000544                      | 1                             | 0        |
| Specific charge (C/kg)           | $-1.758120829 \times 10^{11}$ | 0.5783333629                  | 0                             | 0        |
| Relative charge                  | $-1 \times 10^{-18}$          | $1 \times 10^{-18}$           | 0                             | 0        |
| Spin quantum number              | 1/2                           | 1/2                           | 1/2                           | 1/2      |
| Compton wavelength (m)           | $2.426310241 \times 10^{-12}$ | $1.219011121 \times 10^{-15}$ | $1.219011121 \times 10^{-15}$ | 0        |
| Compton wavelength (Å)           | 24.26310241                   | 0.001219011121                | 0.001219011121                | 0        |
| In Bohr magneton, $\mu_B$        | 1.83615269346                 | 0.0005445726647               | 0.0005445726647               | 0        |
| In nuclear magneton, $\mu_N$     | 1836.15269346                 | 0.0005445726647               | 0.0005445726647               | 0        |

### % Ionic Character of a Single Chemical Bond

Percent ionic character describes the nature of a bond. Bonds possessing 50% or greater ionic character are commonly termed ionic; bonds with less than 50% ionic character are termed covalent. Pauling's equation was modified by Harnay.

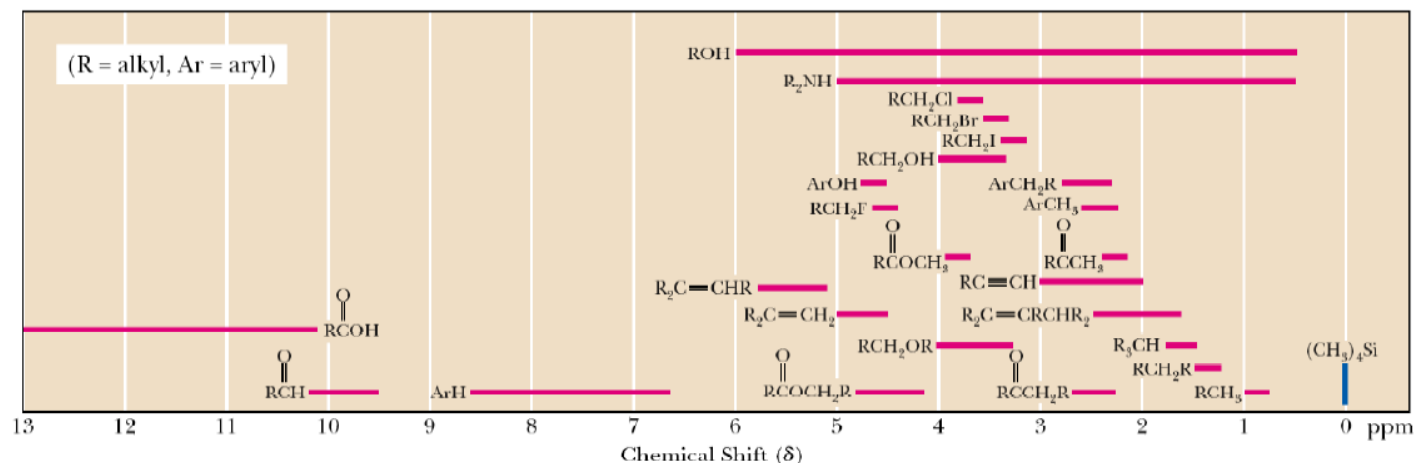
A graph in order to compare bond agreement between experimental and calculated values. Transition from covalent to ionic bonding is usually accompanied by a reduction in electron conductivity, melting point and boiling point.

| Elementary Subatomic Particles   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | % Ionic Character of a Single Chemical Bond |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |                               |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |                               |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|----------------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|---|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|-------------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|-------------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|----------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|-------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|---------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|---------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|----------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|-------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|---------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|-------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|---------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|---------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|-----|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|
| Electron                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Proton                                      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Neutron                       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Photon                        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Neutrino |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Symbol                           |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | e   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | p                             |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | n                             |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $\nu$    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Rest mass (kg)                   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $9.10938291 \times 10^{-31}$                |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $1.672621612 \times 10^{-27}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $1.674927161 \times 10^{-27}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Relative mass (amu)              |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $5.485799091 \times 10^{-4}$                |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $1.007276467 \times 10^{-3}$  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $1.008664916 \times 10^{-3}$  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Particle-antiparticle mass ratio |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1836.15270137                 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1836.68986104                 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Particle-antiparticle mass ratio |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 5.485799091                                 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.000544                      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Specific charge (C/kg)           |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $-1.758120829 \times 10^{11}$               |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.5783333629                  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0                             |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Relative charge                  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $-1 \times 10^{-18}$                        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $1 \times 10^{-18}$           |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0                             |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Spin quantum number              |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1/2   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1/2                           |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1/2                           |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1/2      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Compton wavelength (m)           |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $2.426310241 \times 10^{-12}$               |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $1.219011121 \times 10^{-15}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $1.219011121 \times 10^{-15}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Compton wavelength (Å)           |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 24.26310241                                 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.001219011121                |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.001219011121                |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| In Bohr magneton, $\mu_B$        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1.83615269346                               |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.0005445726647               |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.0005445726647               |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| In nuclear magneton, $\mu_N$     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1836.15269346                               |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.0005445726647               |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.0005445726647               |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 IA                             |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 IIA                                       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 3 IIIA                        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 4 IVA                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 5 VA     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 6 VIA |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 7 VIIA |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 8 VIIIA |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 9 VIIIA |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 VIIIA |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 11 IB |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 12 IIB |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 13 IIIB |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 14 IVB |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 15 VB |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 16 VIB |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 17 VIIB |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 18 VIII |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 H                              |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 He  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 3 Li                          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 4 Be                          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 5 B      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 6 C   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 7 N    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 8 O     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 9 F     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10 Ne    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 11 Na |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 12 Mg  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 13 Al   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 14 Si  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 15 P  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 16 S   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 17 Cl   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 18 Ar   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 19 K                             |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 20 Ca                                       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 21 Sc                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 22 Ti                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 23 V     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 24 Cr |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 25 Mn  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 26 Fe   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 27 Co   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 28 Ni    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 29 Cu |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 30 Zn  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 31 Ga   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 32 Ge  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 33 As |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 34 Se  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 35 Br   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 36 Kr   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 37 Rb                            |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 38 Sr                                       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 39 Y                          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 40 Zr                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 41 Nb    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 42 Mo |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 43 Tc  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 44 Ru   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 45 Rh   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 46 Pd    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 47 Ag |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 48 Cd  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 49 In   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 50 Sn  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 51 Sb |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 52 Te  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 53 I    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 54 Xe   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 55 Cs                            |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 56 Ba                                       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 57 La                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 58 Ce                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 59 Pr    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 60 Nd |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 61 Pm  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 62 Sm   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 63 Eu   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 64 Gd    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 65 Tb |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 66 Dy  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 67 Ho   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 68 Er  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 69 Tm |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 70 Yb  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 71 Lu   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 72 Hf                            |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 73 Ta                                       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 74 W                          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 75 Re                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 76 Os    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 77 Ir |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 78 Pt  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 79 Au   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 80 Hg   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 81 Tl    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 82 Pb |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 83 Bi  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 84 Po   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 85 At  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 86 Rn |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 87 Fr                            |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 88 Ra                                       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 89 Ac                         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Unq                           |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Unp      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Unh   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Uns    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Uno     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Uun     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Uuu      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Uub   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Uuc    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Uud     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Uue    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Uuf   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Uug    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Uui     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Uuj |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 90 Th                            |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 91 Pa                                       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 92 U                          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Np                            |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Pu       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Am    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Cm     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Bk      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Cf      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Es       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Fm    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Md     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | No      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Lr     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

| Compound           |   | pK <sub>a</sub> |
|--------------------|---|-----------------|
| Hydrochloric acid  | $\text{H-Cl}$   | -7              |
| Protonated alcohol | $\text{RCH}_2\text{OH}_2^{\oplus}$  | -2              |
| Hydronium ion      | $\text{H}_3\text{O}^{\oplus}$   | -1.7            |
| Carboxylic acids   | $\text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$   | 3-5             |
| Thiols             | $\text{RCH}_2\text{SH}$   | 8-9             |
| Ammonium ion       | $\text{H}_4\text{N}^{\oplus}$   | 9.2             |
| β-Dicarbonyls      | $\text{RC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{R}'$   | 10              |
| Primary ammonium   | $\text{H}_3\text{N}^{\oplus}\text{CH}_2\text{CH}_3$   | 10.5            |
| β-Ketoesters       | $\text{RC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OR}'$  | 11              |
| β-Diesters         | $\text{ROC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OR}'$ | 13              |
| Water              | $\text{HOH}$  | 15.7            |
| Alcohols           | $\text{RCH}_2\text{OH}$   | 15-19           |
| Acid chlorides     | $\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{Cl}$  | 16              |
| Aldehydes          | $\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$   | 18-20           |
| Ketones            | $\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{R}'$  | 18-20           |
| Esters             | $\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OR}'$   | 23-25           |
| Terminal alkynes   | $\text{RC}\equiv\text{C}-\text{H}$  | 25              |
| LDA                | $\text{H}-\text{N}(\text{i-C}_3\text{H}_7)_2$   | 40              |
| Terminal alkenes   | $\text{R}_2\text{C}=\underset{\text{H}}{\text{C}}-\text{H}$   | 44              |
| Alkanes            | $\text{CH}_3\text{CH}_2-\text{H}$   | 51              |

| Type of Hydrogen<br>(R = alkyl, Ar = aryl)        | Chemical Shift ( $\delta$ )* | Type of Hydrogen<br>(R = alkyl, Ar = aryl)                                     | Chemical Shift ( $\delta$ )* |
|---|------------------------------|--|------------------------------|
| $R_2NH$   | 0.5-5.0                      | $RCH_2OH$  | 3.4-4.0                      |
| $ROH$   | 0.5-6.0                      | $RCH_2Br$  | 3.4-3.6                      |
| $RCH_3$   | 0.8-1.0                      | $RCH_2Cl$  | 3.6-3.8                      |
| $RCH_2R$  | 1.2-1.4                      | $\begin{array}{c} O \\    \\ RCOCH_3 \end{array}$                              | 3.7-3.9                      |
| $R_3CH$   | 1.4-1.7                      | $\begin{array}{c} O \\    \\ RCOCH_2R \end{array}$                             | 4.1-4.7                      |
| $R_2C=CRCHR_2$                                    | 1.6-2.6                      | $RCH_2F$   | 4.4-4.5                      |
| $RC\equiv CH$                                     | 2.0-3.0                      | $ArOH$   | 4.5-4.7                      |
| $\begin{array}{c} O \\    \\ RCCH_3 \end{array}$  | 2.1-2.3                      | $R_2C=CH_2$  | 4.6-5.0                      |
| $\begin{array}{c} O \\    \\ RCCH_2R \end{array}$ | 2.2-2.6                      | $R_2C=CHR$   | 5.0-5.7                      |
| $ArCH_3$  | 2.2-2.5                      | $\begin{array}{c} O \\ \diagup \quad \diagdown \\ H_2C \quad CH_2 \end{array}$ | 3.3-4.0                      |
| $RCH_2NR_2$                                       | 2.3-2.8                      | $\begin{array}{c} O \\    \\ RCH \end{array}$                                  | 9.5-10.1                     |
| $RCH_2I$  | 3.1-3.3                      | $\begin{array}{c} O \\    \\ RCOH \end{array}$                                 | 10-13                        |
| $RCH_2OR$   | 3.3-4.0                      |  |                              |

\* Values are relative to tetramethylsilane. Other atoms within the molecule may cause the signal to appear outside these ranges.



Use this page for scratch if you would like. For your reference, here are the Golden Rules of Chemistry:

**A. Predicting Structure and Bonding** 1. In most stable molecules, all the atoms will have filled valence shells. 2. Five- and six-membered rings are the most stable. 3. There are two possible arrangements of four different groups around a tetrahedral atom.

**B. Predicting Stability and Properties** 4. The most important question in organic chemistry is "Where are the electrons?" 5. Delocalization of charge over a larger area is stabilizing. 6. Delocalization of unpaired electron density over a larger area is stabilizing. 7. Delocalization of pi electron density over a larger area is stabilizing.

**C. Predicting Reactions** 8. Reactions will occur if the products are more stable than the reactants and the energy barrier is low enough. 9. Functional groups react the same in different molecules. 10. A reaction mechanism describes the sequence of steps occurring during a reaction. 11. Most bond-making steps in reaction mechanisms involve nucleophiles reacting with electrophiles.