How to Identify Strong Nucleophiles

Let's begin with simple definitions.
An electrophile is an electron acceptor. It is the "acceptor" of the reaction mechanism arrow.
A nucleophile is the opposite: an electron donor. It is the "source" of the reaction mechanism arrow.
A leaving group (LG) is "an atom or group of atoms which break away from the rest of the molecule, taking with it the electron pair which used to be the carbon-leaving group bond" (Lecture Supplement, pg. 5).

A basic SN2 reaction is shown below, labeled with the important terms I have defined above. Notice that nucleophile is denoted by "Nu−" and the leaving group is denoted by "L." The electrophile is the entire CXYZ reactant. (Although SN2 mechanisms will not be discussed in this worksheet, the image is helpful nonetheless.)

\[
\text{Nu}^- + \text{C}_{\text{XY}}\text{Z} \rightarrow \text{Nu} - \text{C}_{\text{XY}}\text{Z} + \text{L}
\]

Now that we have a basic understanding of what nucleophiles and leaving groups are, let's discuss what properties can make them stronger/poorer.

**First, we will look at contributors in regard to nucleophilicity.** As a generalization that will be explained later, better nucleophiles have "unhappy" electrons. Unhappy electrons result in instability, and motivation for a reaction to occur.

1. **Resonance**
   Resonance is absolutely essential in organic chemistry. According to Dr. H's illustrated glossary, resonance is "a condition in which molecular structure cannot be adequately represented by a single Lewis structure; two or more Lewis structures are required."

   The result of this? Electron delocalization. This means that a molecule with resonance can better accommodate electrons. Thus, resonance is a stabilizing feature. In other words, the more resonance a molecule has, the "happier" its electrons are.

   But nucleophiles want their electrons to be poorly accommodated; they need their electrons to be unhappy so that a reaction can occur. Nucleophiles are inclined to share electrons, which is easier to do with poorly accommodated electrons.

   **We conclude that resonance—sometimes but not always—decreases nucleophilicity.**

   (For instances where resonance does not influence nucleophilicity, see page 17 of the Lecture Supplement.)

2. **Atomic Radius**
   Consider an atom's size. The larger an atom, the less concentrated its electron density is. Hence, a large atom has better accommodated electrons; its electrons are "happier." This, in turn, decreases nucleophilicity.

   **We conclude that larger atomic radius decreases nucleophilicity.**

3. **Electronegativity**
   Now, let us consider electronegativity. Electronegativity is essentially an atom's electron greediness. An atom with high electronegativity wants to keep, not share, electrons. By definition, this is the exact opposite of a nucleophile!

   **We conclude that high electronegativity reduces nucleophilicity.**

4. **Inductive Effects**
   Inductive effect is the "transfer of charge (electron withdrawal or donation) through a chain of atoms in a molecule by electrostatic induction" (Lecture Supplement, pg23). Essentially, the atom that withdraws electron density towards itself means reduced electron density at the "business end." Reduced electron density throughout the molecule means better electron accommodation, and thus "happier" electrons.

   **We conclude that inductive effect reduces nucleophilicity.**

   Note that inductive effect (1) is dependent on electronegativity and quantity, and (2) decreases with distance. To better understand this, take a look at the online diagrams I found below.

   In the following images, notice that "most acidic" can be replaced by "poorer nucleophile", if the acid shown is deprotonated. Also, "least acidic" can be replaced by "better nucleophile", if the acid shown is deprotonated.

5. **Formal Charge**
   In particular, a negative charge signifies an electron excess. So, the molecule is "unhappy" with a charge: it is unstable and seeks to share these electrons.

   **We conclude that negative formal charge enhances nucleophilicity.**

As of now, we have discussed all the contributors for nucleophilicity. But what takes precedence? In general, the contributor importance is as follows:

- resonance > atomic radius > electronegativity > inductive effect with formal charge on the side.
Works Cited:

