Most people who routinely use pesticides are familiar with the term active ingredient. The active ingredient is the component of a pesticide formulation responsible for its toxicity (phytotoxicity for herbicides) or ability to control the target pest. The active ingredient is always identified on the pesticide label, either by common name (atrazine, bentazon, for example) or chemical name (2,4-dichlorophenoxy acetic acid, diglycolamine salt of 3,6-dichlor-o-anisic acid, for example). The active ingredient statement may also include information about how the product is formulated and the amount of active ingredient contained in a gallon or pound of formulated product. For example, the Basagran label indicates the active ingredient (bentazon) is formulated as the sodium salt, and one gallon of Basagran contains four pounds of active ingredient.

Usually, when a herbicide trade name is followed by a number and letter designation (4L, 75DF, 7EC, etc), the number indicates how many pounds of active ingredient are in a gallon (for liquid formulations) or pound (for dry formulations) of the formulated product. The formulation designations for Basagran 4L, AAtrax 90DF, and Prowl 3.3EC indicate Basagran 4L contains 4 pounds of active ingredient (bentazon) per gallon of formulated product, AAtrax 90DF contains 0.90 pounds of active ingredient (atrazine) per pound of formulated product, and Prowl 3.3EC contains 3.3 pounds of active ingredient (pendimethalin) per gallon of formulated product, respectively.

**Active Ingredient (AI)**

Some herbicides (atrazine for example) have specific maximum per year application rates that cannot be exceeded. These maximum per year application rates are generally presented in terms of the total amount of active ingredient that can be applied per year. How would one calculate the pounds of active ingredient applied at a given product use rate? There are several calculations that can be used to determine the amount of active ingredient applied at a given product use rate. One of the easiest calculations is:

\[
\text{pounds active ingredient applied per acre} = \frac{\text{gallons or lbs of product applied}}{\text{acre}} \times \frac{\text{lbs active ingredient}}{\text{gallon or lbs of product}}
\]

Using this equation, we can calculate the amount of active ingredient (bentazon) which is applied when we apply 2 pints (0.25 gallon) per acre of Basagran 4L:

\[
\text{pounds of bentazon (active ingredient) applied per acre} = \frac{0.25 \text{ gallon of product applied}}{\text{acre}} \times \frac{4 \text{ lbs active ingredient}}{\text{gallon of product}} = 1 \text{ pound active ingredient per acre}
\]

**Acid Equivalent (AE)**

Sometimes, however, the numbers preceding the formulation designation (L, EC, DF, etc.) do not indicate pounds active ingredient per gallon or pound, but rather the acid equivalent per gallon or pound. The term acid equivalent is one that many people are less familiar with. Acid equivalent may be defined as that portion of a formulation (as in the case of 2,4-D ester for example) that theoretically could be converted back to the corresponding or parent acid. Another definition of acid equivalent is the theoretical yield of parent acid from a pesticide active ingredient which has been formulated as a derivative (esters, salts, amines are examples of derivatives). For instance, the acid equivalent of the isooyctyl ester of 2,4-D is 66% of the ester formulation, but 88% of the ethyl acetate ester formulation.

Why would a herbicide (one that has the acid as the parent molecule) be formulated as a derivative (ester, salt, amine, etc.) of the parent acid?

Herbicidal activity refers to the ability of a particular herbicide to effectively bind to a target site within the plant and exert some type of lethal effect (i.e., you apply the herbicide to the plant and the plant eventually dies). A herbicide molecule may sometimes be altered to impart some property other than herbicidal activity. Such alterations are possible with herbicide molecules that are acids (for example, molecules that have a carboxyl group as part of their structure). The acidic carboxyl hydrogen is replaced by the desired ions to form a salt or reacted with an alcohol to form an ester. Why would this be done? One example might be that due to the chemical characteristics of a particular herbicide molecule, the parent acid may not be readily absorbed into a plant because it’s not able to effectively penetrate the waxy cuticle covering the leaf. Somehow altering the parent acid may increase the ability of the herbicide to penetrate through the leaf much more effectively. For some postemergence herbicides, formulating the parent acid as an ester or salt is frequently done to facilitate absorption through the leaf. Other formulations or derivatives of the parent acid may increase the water solubility of the herbicide. 2,4-D (2,4-dichlorophenoxy acetic acid) is commonly formulated as an ester or amine. The ester formulation increases the lipid solubility of the herbicide, which allows it to more easily penetrate the waxy cuticle of the plant leaf. The amine formulation greatly increases the water solubility of the herbicide, which may be desirable if the product needs to be moved into the soil solution for root uptake (brush control, for example).

If a herbicide is formulated as a derivative of the parent acid, it is important to remember the parent acid is the herbicidally active portion of the formulation. The parent acid is what binds to the herbicide target site within the plant and causes plant
The acid equivalent of the isopropylamine salt formulation is 245. The molecular weight of the isopropylamine salt is 59 (weight of the ammonia molecule in the salt) + 169 (weight of the parent acid) = 228. The molecular weight of the trimesium salt is 169 (weight of the parent acid) + 169 (weight of the trimesium molecule) = 338. So, we now need to provide some molecular weights (i.e., how much the molecule weighs) to complete these calculations. The molecular weight of the parent glyphosate acid is 169. The molecular weight of the isopropylamine salt is 59 (weight of the three carbons, ten hydrogens, and one nitrogen atom) + 169 (weight of the parent acid) = 228. The molecular weight of the trimesium salt formulation is 245.

The acid equivalent of the isopropylamine salt formulation is:

\[
\text{Acid Equivalent} = \frac{169 - 1}{228} \times 100 = 74\%
\]

So the amount of acid equivalent in one gallon of formulated product is:

\[
74\% \text{ acid equivalent} \times \frac{5 \text{ lbs active ingredient}}{\text{gallon}} = 3.70 \text{ lbs ae}
\]

The acid equivalent of the trimesium salt formulation is:

\[
\text{Acid Equivalent} = \frac{169 - 1}{245} \times 100 = 69\%
\]
So the amount of **acid equivalent** in one gallon of formulated product is:

\[
69\% \text{ acid equivalent} \times \frac{5 \text{ lbs active ingredient}}{\text{gallon}} = 3.45 \text{ lbs ae}
\]

Again, we applied 28 ounces (0.22 gallon) per acre of each formulation, and since they both contain five pounds active ingredient per gallon, the amount of **active ingredient** applied is equal. The amount of **acid** applied (that part of the formulation that actually controls the weed) for each formulation is NOT equal:

The amount of **acid** applied per acre with the **isopropylamine salt** formulation is:

\[
\frac{\text{pounds acid equivalent applied per acre}}{\text{gallon of product applied}} = \frac{0.22 \text{ gallon of product applied}}{\text{acre}} \times \frac{3.70 \text{ lbs ae}}{\text{gallon of product}} = 0.81 \text{ lbs ae per acre}
\]

The amount of **acid** applied per acre with the **trimesium salt** formulation is:

\[
\frac{\text{pounds acid equivalent applied per acre}}{\text{gallon of product applied}} = \frac{0.22 \text{ gallon of product applied}}{\text{acre}} \times \frac{3.45 \text{ lbs ae}}{\text{gallon of product}} = 0.76 \text{ lbs ae per acre}
\]

This example demonstrates that there was more **acid** applied with the isopropylamine salt formulation than with the trimesium salt formulation. In practical terms, more of the part of the formulation that actually controls the weeds was applied with the isopropylamine formulation. To compare the herbicidally active portion of two ester, salt, or amine formulations, product equivalents should be based on the **acid equivalent** of a salt, amine, or ester formulation.

This exercise was done not to add confusion but to illustrate that to calculate equivalent rates of salt or ester formulations, the **acid equivalent** calculation should be used. If there is only one formulation of a salt or ester product commercially available, it wouldn’t really matter if one calculated active ingredient or acid equivalent. For example, Pursuit is formulated as the ammonium salt of imazethapyr, but currently only one manufacturer markets Pursuit. There are, however, several commercial formulations of 2,4-D and glyphosate. Currently over 20 different commercial formulations of glyphosate available today, and likely more will be available in the future. Not all of these formulations contain the same amount of **acid equivalent** so if you want to determine equivalent rates of two glyphosate-containing formulations with respect to how many molecules of glyphosate are applied, you must calculate these rates based on **acid equivalent**. When calculations are based on the same acid equivalent the amount of formulated product applied may not always be equal. **It is the acid portion of a salt formulation that binds at the target site.**

**Will differences in the amount of acid equivalent applied between two formulations result in weed control differences?** One might argue that if the difference in amount of acid applied is large enough differences in weed control might result, and might be noticed on weeds the herbicide is “marginal” against. However, it is difficult to make an all inclusive statement that weed control differences will always result if differing amounts of acid are applied, especially when the difference in amount of acid applied is small. Labeled application rates are established by herbicide manufacturers based on product testing. It does not seem very likely that a herbicide manufacturer would market a herbicide at an application rate that would consistently result in reduced weed control compared with a competitive formulation.