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WINE CHEM 101

By Bob Peak

A few months ago, ***Winemaker*** magazine publisher Brad Ring invited Byron Burch to speak about meadmaking at the magazine's first annual home winemaking conference. They both thought my degree in chemistry might combine well with my experience as a Beverage People partner to bring some wine science to the masses—and Wine Chem 101 was born.

To my surprise, every one of the room's 100 seats was occupied on a Saturday morning at the Doubletree Hotel in Rohnert Park—for a chemistry lesson! The hour lecture and discussion covered several of the most important chemistry characteristics of grape juice, wine, and winemaking. I will now continue the dialog, one topic at a time for the always-popular Beverage People News and catalog.

Before we get into the specific chemistry of wine, it's important to review a little bit about the study of chemistry itself. Chemists usually talk about chemical reactions in "equilibrium" terms. That is, we look at what goes into a reaction and what comes out of it, without considering very much the amount of time it takes. We treat it as though the reaction happened instantly, much like adding vinegar to baking soda and getting the immediate acid-base reaction that results. As an analogy, if recipes were written the way chemical reactions usually are, we would bake a cake by telling you the ingredients and baking temperature, but ignoring the time. A cake just comes out. For most chemical reactions most of the time, ignoring time like this has no significant consequences.

Not so for wine chemistry. Many of the important chemical reactions in wine take time to occur. It may take hours for color extraction in a rose, several days for alcoholic fermentation, months to complete the cold stabilization of tartrates, and years to produce the character we call "aged." Whenever we talk about time as a variable in chemical reactions, the field we are studying is "kinetics". Although some chemists devote their research careers to that, I'll mostly treat these chemical reactions of wine as equilibrium situations.

So why chemistry? Without knowing some of the chemistry of wine, a home winemaker may be flying blind—or at least wearing dark glasses with the lights off. Things go in—grapes, yeast, nutrients—and wine comes out. Sort of. With a little chemistry, you can greatly improve your odds of producing excellent wine every vintage. And if you memorize a few of these chemistry facts, you can amaze your friends next time you go wine tasting!

There are hundreds of chemical compounds that have been identified in wine, beyond those in grapes to start with. For our chemistry discussion, though, I want to concentrate on a few of the most significant components of wine. As we displayed with our graduated-cylinder graphic in last year's newsletter, wine is mostly water. After the 85-90% water, there is some 10-15% alcohol (ethanol), 0.4–0.7% fixed acids, 1-2% other organic molecules, and less than one-half of one percent minerals, usually reported as "ash".

We will skip over water chemistry for this discussion, and begin with the production of alcohol from grape sugars. This conversion—the one we call "fermentation"—is obviously the most important chemical reaction a hobbyist encounters in pursuing the miracle that is winemaking. First, there is the sugar. Cane sugar, sucrose, is a 12-carbon molecule consisting of two six-carbon rings which are held together by a fairly weak bond. Sucrose is the sugar we most often encounter in daily life and is present in many fruits and vegetables. However, under acid conditions, the weak bond holding the two rings together will break. The two resulting six-carbon molecules are themselves sugars: glucose and fructose. Since each of these contains six carbon atoms, they are collectively called “hexoses” (hex- for six and –ose for sugar). Because wine grapes are high in acid (low in pH), these two are the sugars of grapes, generally in about a 50-50 mix. Both glucose and fructose have the same chemical formula:

$C_6H_{12}O_6$

Although the molecules differ in structural details, that feature is not significant for this discussion and we can generally treat them as identical in chemical reactions. *One small exception with regard to wine is that most wine yeasts are considered “glucophilic” or glucose-loving. That means a stuck fermentation, with only a little bit of sugar left to ferment out, will contain primarily fructose. So what is left near the end is exactly the sugar that is most difficult to restart.*
Ethanol, the alcohol of wine, is a two-carbon compound

C_2H_5OH

So for fermentation, we need to take our six-carbon sugar down to a two-carbon alcohol. In basic chemical notation, it is simple and looks like this:

$C_6H_{12}O_6$ _ 2 C_2H_5OH + 2 CO_2
Hexose _ 2 Ethanols + 2 Carbon Dioxides

The reaction products, by weight, are 51.1% ethanol and 48.9% carbon dioxide. The 51.1% by weight would calculate out as 59% by volume, relative to the water in the finished wine. Actual yield of alcohol is a bit lower, due to evaporation during fermentation and conversion of alcohol to other byproducts. We usually use a figure of 55% as a reasonable practical predictor of alcohol in a finished wine. *So, degrees brix (percent sugar by weight) times 0.55 (55%) equals alcohol by volume in the finished wine.* For example, at 20° Brix, 20 x 0.55 = 11% alcohol by volume.

Of course, real life is never as simple as the chemical equation displayed above and the yeast does not just jump from six-carbon sugars to two-carbon alcohol. The yeast itself is using energy from these chemical reactions to live and reproduce. There are fifty or more enzyme-mediated reactions going on within the yeast cell during the cascade from sugar to alcohol. I will not review them all here, but will cover a few major steps along the way. First, the six-carbon ring is broken into two three-carbon pyruvates. From there, if oxygen is present, yeast can oxidize the pyruvates all the way down to carbon dioxide and water—no alcohol! That is why fermentation is carried out with little or no oxygen present, after the initial build-up of yeast. The rapid evolution of carbon dioxide—and a fermentation lock on whites and rosés— keeps the environment essentially oxygen-free. Under those conditions, each three-carbon pyruvate is further converted into a two-carbon acetaldehyde. One carbon dioxide molecule is ejected with each acetaldehyde. Then each acetaldehyde is itself reduced to an ethanol molecule. Now we have a solution of alcohol and water, maybe with a little sugar left in it. Sounds like a pretty boring beverage—so what gives wine its zing? In a word -Acid.

But to keep this overview from overwhelming our readers, I'll save the discsussion of Acid for our next installment, part B of Wine Chem 101.

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