WINE COMPOSITION AND CHEMISTRY

CHAPTER ONE

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LEARNING OBJECTIVES

After studying this chapter, the candidate should be able to:

- Recognize the main categories of chemical compounds in wine.
- Identify the approximate concentrations of the major components of wine.
- Describe the specific types of alcohols, acids, and sugars that are most prominent in wine.
- Discuss the types of phenolic compounds that are important in wine.

Wine is the fermented product of grapes. Although beverages such as strawberry wine and rice wine are produced with other raw materials, the unmodified term in the United States legally refers to a beverage made from grapes. Of all the types of fruit in the world, grapes have the most valued combination of fermentable sugars, significant acidity, desirable flavors, and liquid content to make a complex beverage like wine.

From the scientist's point of view, wine is a complex blend of chemicals that collectively give the liquid its visual, olfactory, and tactile characteristics. Many chemical compounds found in wine originate in the grapes themselves and remain in the liquid from the wine press to the bottle. Others are created during the fermentation process through the action of yeast cells. Still others occur along the way in purely chemical reactions when molecules interact, break apart, and recombine as new compounds.

Many of these chemical reactions continue to expand and evolve over time. As a consequence, the concentrations of some compounds increase as a wine ages, while others decrease with time, resulting in a wine's ever-changing character. While some wines become more complex and desirable with time, others begin to fade soon after bottling. However, the truth remains that with sufficient time, nearly all wines are overcome by undesirable components as the chemical reactions reach their final stages.

The major components of wine include the following:

- Water
- Alcohol
- Acid
- Sugar
- Phenolic compounds

Various impurities such as bacteria may also be present in wine, but modern winemaking techniques usually reduce the amount of any unintended components to a negligible level. Other compounds, such as yeast or proteins, may be present in very small concentrations in some wines, particularly those that have undergone extensive aging in contact with yeast cells.

WINE COMPONENTS

WATER

Wine is typically 80–90% water. The water in wine is primarily from the grapes themselves, although small amounts of water may be added incidentally during winemaking. Although an uncommon practice, in some situations the winemaker will intentionally add water to dilute grape juice or wine when potential alcohol, actual alcohol, or phenolic compounds are beyond desired levels.

ALCOHOL

After water, the most prevalent ingredient in wine is alcohol, which is usually 10–15% of the volume, although there are certainly many examples of wines that contain more or less than this average amount. *Ethyl alcohol*, also referred to as *ethanol*, is the primary result of alcoholic fermentation and the main alcohol component of wine. Other types of alcohol that occur in smaller amounts include *glycerol* and *methyl alcohol* (or *methanol*), as well as a group of compounds known as *fusel alcohols* (*fusel oils*) or *higher alcohols*.

Alcohol is the intoxicating element in wine and is what distinguishes wine from grape juice. Ethanol is a volatile compound, which means that it evaporates easily. When it does, it carries the wine's aromas to the nose.

Alcohol content is one element that contributes to the mouth-filling, tactile sensation of a wine as it rests on the palate; this sensation is often referred to as a wine's "weight" or "body." Wines with higher levels of alcohol tend to be heavier in weight than wines with lower levels of alcohol, all other things being equal. High levels of alcohol can also result in slow, thick-appearing "tears" or "legs" in the glass after the wine is swirled.

Figure 1–1: Wine diamonds

ACID

Water and alcohol are essential to wine, but it is the other components that make each wine unique. A variety of acids, especially in white wines, give the wine much of its structure, balance, and thirst-quenching refreshment. Acids usually make up between 0.5% and 0.75% of a wine's volume.

The principal acids in wine include the following:

- ***Tartaric acid***
  Tartaric acid is the most prevalent of the acids found in both grapes and wine. It is also the strongest in terms of pH. Tartaric acid also has a unique propensity to form solid crystals at low temperatures. These crystals are known as tartrates, or "wine diamonds" if found in wine. Once tartaric acid takes this form, it will not redissolve into the liquid, and the wine will become noticeably less acidic. Tartrate crystals are not considered a defect in most wines; however, the formation of tartrates in bottled wine can be avoided or minimized via the winemaking process of cold stabilization (see chapter five).
- ***Malic acid***
  Malic acid is a sharp-tasting acid frequently associated with green apples. Underripe grapes and cool-climate grapes are typically high in malic acid. However, the level of malic acid decreases during the ripening phase of the grapes on the vine. Wines made from overripe grapes or grapes grown in hot climates tend to have relatively low levels of this acid. High levels of malic acid can be assuaged using the winemaking technique known as *malolactic fermentation*.
- ***Citric acid***
  Citric acid is not usually considered to be a normal component of grapes, as it exists in such minute quantities that specialized equipment is required to measure it. Therefore, it has no sensory impact on the majority of wines. However, citric acid is sometimes added to increase the total acidity in a wine, although its distinctive citrus fruit flavor makes it generally unsuitable for quality wines.

- ***Lactic acid***
  Lactic acid is not found in grapes; rather, it is created in wine by lactic acid bacteria, which convert malic acid into lactic acid in the optional winemaking process known as malolactic fermentation. As lactic acid is less intensely acidic than malic acid, wines that undergo malolactic fermentation tend to be softer and smoother in mouthfeel than those that do not. The by-products of malolactic fermentation also provide wine with a creamy texture and, in some cases, a "buttery" aroma. Lactic acid is also created during primary fermentation, albeit in very small amounts.
- ***Acetic acid***
  Acetic acid is the acid found in most types of vinegar. A low level of acetic acid is typically created during fermentation. Unlike the other acids discussed above, acetic acid is volatile, so it readily evaporates and joins the aromas of the wine, adding to the complexity of a wine's bouquet, particularly in red wines. However, higher concentrations, typically the result of a chemical reaction between ethanol and oxygen caused by harmful (to wine) bacteria called *acetobacter*, can be unpleasant and may make a wine undrinkable.
- ***Succinic acid***
  Succinic acid is a minor component in grapes and a by-product of normal alcoholic fermentation. Succinic acid has a sharp, slightly bitter, slightly salty flavor.

GRAPE ACIDS	FERMENTATION ACIDS
Tartaric Acid	Lactic Acid
Malic Acid	Acetic Acid
(Citric Acid)	Succinic Acid
(Succinic Acid)	

Total Acidity and pH

Two numbers are used to describe the acidity level of a wine. One is for *total acidity* (TA), which is the volume of all the acids in a wine. In general, more acid equates to a more acidic taste. However, TA includes several different acids, some of which are stronger than others. For that reason, a second measurement, *pH*, is also used.

The pH level of a wine represents the combined chemical strength of the acids present. Wine usually measures between 2.9 and 3.9 on the logarithmic pH scale. A *lower* pH indicates a *stronger* acid content. Thus, a wine with a pH of 2.9 will be more acidic than a wine with a pH of 3.4. To get a complete picture of a wine's acidity, you need to know both its TA and pH. However, winemakers place particular emphasis on pH, as it gives an indication of stability and plays a role in determining sulfur additions.

SUGAR

Grapes typically contain 15% to 28% sugar at harvest. More specifically, the grapes contain roughly equal amounts of two sugars:

- Glucose
- Fructose

Glucose and fructose are both highly fermentable monosaccharides, commonly known as "simple sugars." During fermentation, given the right conditions, yeast converts these sugars into ethanol, turning grape juice into wine. If the yeast is both able to and allowed to finish the job, the wine will be fermented to dryness. However, even dry wines contain a trace amount of sugar, as grapes actually contain tiny quantities of unfermentable sugars. These unfermentable sugars generally remain in concentrations below one's ability to detect them.

Wines that have less sugar than a person can taste are described as *dry*. However, many wines do have detectable sugar. This is generally because the fermentation was stopped, through

winemaker intervention or by natural causes, before all of the sugar was converted to alcohol. Depending on the amount of residual (remaining) sugar, the wines may be called *off-dry* (sometimes referred to as *medium dry*), *medium sweet*, or *sweet*. Residual sugar can add weight and viscosity to a wine, and as such—particularly in the case of sweet wines—can influence the mouthfeel, body, and texture of a wine.

The presence of sugar after fermentation adds a new dimension to the taste of a wine, which may be desirable or not, depending on the situation. Some of the world's most renowned dessert wines are extremely sweet, even up to 24% or more residual sugar. In other cases, a small amount of sweetness is used to balance high acidity in a wine, or vice versa. In some lower-quality wines, sweetness may be used to hide the wine's minor flaws.

The production of sweet wines will be covered in more detail in chapter 5.

PHENOLIC COMPOUNDS

Phenolic compounds (also known as *phenolics*, *polyphenolics*, or *polyphenols*) are a large category of various molecules that are present in many wines. Phenolics occur in wine in minute quantities, yet they can have a major impact on the sensory profile of a wine.

Phenolics include the following:

- ***Anthocyanins***
  Anthocyanins are compounds that give red wine its color, which in fact ranges from blue to purple to red. The color of a red wine is influenced by both the amount of anthocyanins and the acidity level of the wine; more acidic wines appear redder in hue, while less acidic ones appear bluer.

- ***Flavonols***
  These yellow pigments are found in white wines. Flavonols (sometimes called *flavones*) increase in grapes with increased

exposure to sunlight; therefore, white wines from sunnier climates tend to have a more golden color than white wines from cooler (or cloudier) climates.

- ***Tannins***
  Tannins are astringent, bitter compounds found in the skins, seeds, and stems of grapes. They are also found in oak and oak barrels. These compounds form part of the structure, or "backbone," of big red wines. Tannins are a natural preservative and help to protect red wines from oxidation during the aging process. When present in a young wine, tannins are easily recognizable by the textural, drying sensation they create in the mouth.

- ***Vanillin***
  Vanillin is an aromatic phenolic compound in oak that imparts a vanilla scent to barrel-aged wines. While vanilla aromas are often associated with American oak, the amount of vanillin present in the wood varies according to several factors—including the level of seasoning used in the preparation of the barrel and the age and size of the barrel—as well as species of oak. In general, the level of vanillin increases (as compared to raw oak) with light to medium toast levels and may decrease with the use of heavier levels of toast.

- ***Resveratrol***
  A compound in wine believed to have several beneficial health effects in humans, resveratrol is discussed in more detail in chapter 22.

The phenolics of a grape are concentrated primarily in its skin and seeds. Because of this, red wines, which are fermented in contact with the grape solids, are much richer in phenolic compounds than white wines.

Over time, some phenolic compounds, particularly tannins and pigments, tend to polymerize, or combine into longer molecule

chains. These chains may eventually become too heavy to stay suspended in the liquid and may drop out of the solution as sediment. This development has a major impact on the flavor of the wine and is one of the main results of the aging process. In many cases, the production of sediment in a properly-aged red wine renders a wine lighter in color and less astringent. However, it should be noted that new research indicates that polymerized tannins can possibly continue to alter in structure and may eventually break down during extended aging; thus it may be impossible to predict how the tannins in a well-aged wine will be perceived by the taster.

OTHER COMPONENTS

- ***Aldehydes***
  Aldehydes are oxidized alcohols that are formed when wine is exposed to air. Some wines such as Sherry and Madeira are made using techniques that encourage the formation of aldehydes, but any wine will take on an oxidized or "maderized" character if it has been exposed to excessive oxygen during production or storage. Wines may also become oxidized after being open too long or exposed to heat. The most common aldehyde in wine is *acetaldehyde*, which is formed by the oxidation of ethanol. Acetaldehyde contributes to the distinctive aroma of fino Sherry.

- ***Esters***
  Esters are molecules that result from the joining of an acid and an alcohol. They represent the largest group of odiferous compounds found in wine. Most are desirable at low concentrations, but some are considered off-odors when found in high enough concentrations. One of the most common esters in wine is *ethyl acetate*, the ester of acetic acid and ethanol. At low concentrations, ethyl acetate imparts a fruity, flowery aroma; however, at high concentrations, it may impart the faulty aromas of nail polish remover, varnish, or glue.

- ***Dissolved gases***
  Dissolved gases are inevitably present in any liquid, although they are not necessarily present in significant concentrations. In wine, dissolved oxygen promotes many chemical reactions through the process known as *oxidation*. While this may be beneficial to some wines, it can also be damaging. Thus, winemakers try to avoid air exposure and often add sulfur during the winemaking process in order to absorb any free oxygen molecules before these molecules have the opportunity to harm the wine.

  Another dissolved gas routinely found in wine is carbon dioxide (CO2). This gas is what gives sparkling wine its bubbles. Carbon dioxide is a natural by-product of fermentation. Small amounts are present even in still wines, and some winemakers leave enough carbon dioxide in their wines to create a bit of petillance (slight bubbling under the surface) when the wine is poured. The CO2 in wine keeps a wine feeling fresh and lively in the mouth and promotes the release of the wine's aromatic compounds.

- ***Sulfites***
  Sulfites are a class of chemicals that are based on the element sulfur. Sulfur is an important preservative that is widely used to keep wines stable after fermentation. Sulfur is also produced in minute quantities as a natural by-product of fermentation. Therefore, all wines contain at least trace amounts of sulfites even if no sulfur is added during winemaking. As sulfur is an antioxidant and an antibacterial agent, producing wine without the addition of sulfur is very challenging. Some people are extremely sensitive to sulfur and can have negative reactions to it. Therefore, wines destined for interstate commerce in the United States that contain more than 10 parts per million (ppm) of sulfur dioxide are required to display the "Contains Sulfites" warning on the label.