Objective: Consider using muscadine for sparkline wine

- Sparkling Wine in Florida
- What is Sparkling Wine
- Why Carbonate
- Methods of Carbonation
- Methods for Muscadine
- Future Project

- Nearly 1.6 million gallons of wine were produced in the state of Florida during 2017[1]
- At ~ 21 million people - less than a bottle per person
- Only a fraction of Florida wineries produce carbonated wine products

US / California Wine Production

California produces an average of 81 percent of total U.S. wine production.

(In gallons)

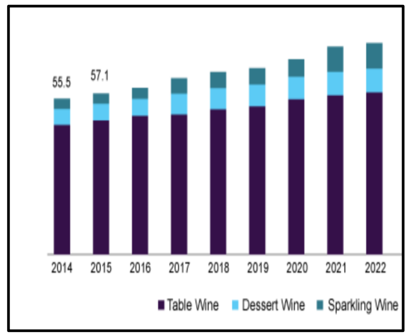
Year	California*	U.S.*
2017	716,309,505	888,582,343
2016	680,272,512	806,447,891
2015	638,173,762	768,088,776
2014	709,647,220	835,468,643
2013	728,939,759	836,106,493
2012	662,818,311	752,431,183
2011	605,619,613	683,623,267
2010	606,448,660	677,490,922

https://www.wineinstitute.org/resources/statistics/article83

[1]Alcohol Tobacco Tax and Trade Bureau (TTB)

- There is increased consumption of carbonated wines throughout the world, and sparkling wine is the fastest growing sector in the wine industry[1]
- Carbonation beverage sales were up 56% in 10 years — and had nearly a 6% growth last year (2017)[2].
- Also, younger wine drinkers appear to be the most eager to consume sparkling wine throughout the year, and this consumption trend is predicted to continue (Figure 1)[3].

U.S. Wine Market Size (USD billion)



[1]Wine Handbook (2018),
[2]Beverage Information and Insights Group (2017)
[3]Laurie Daniel. October 2018. “Sparkling Wine Trends in 2018” Beverage dynamics

Still Wine Production

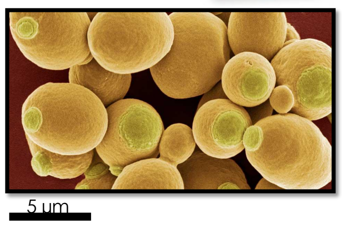
Processing steps:

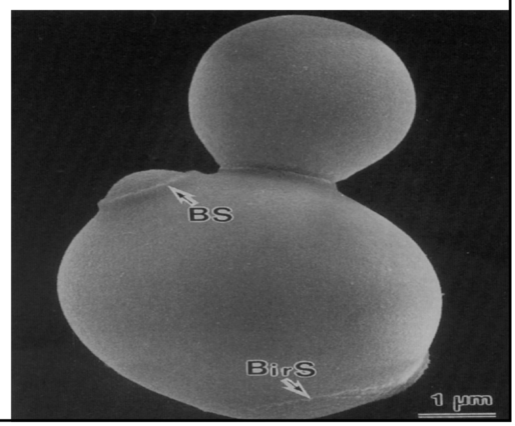
- **Grape pressing**
- **Pasteurization of must/grape juice**
- **Yeast addition (pitching, $10^{6\text{-}7}$ cells/mL *Saccharomyces cerevisiae*)**
- **Fermentation of must**
  - (3-5 days at 20-28°C for red wines, whites are fermented at 10-18°C for 7-14 days)
  - *Yeast (S. cerevisiae)* converts the must sugar to alcohol
  - Alcohol concentration depends on initial sugar content
  - Most wine strains will stop fermentation at 18% v/v alcohol which becomes inhibitory to the yeast cell
  - Wine pH very low at around 3.5 which is inhibitory to bacterial pathogens (but not spoilage organisms)
- **Additives**
  - Sulphur dioxide (about 50 mg/L)
  - To inhibit yeast & bacteria
- **Settling vat (removal of yeast, malolactic fermentation)**
- **Aging**
- **Bottling**

Fermentation

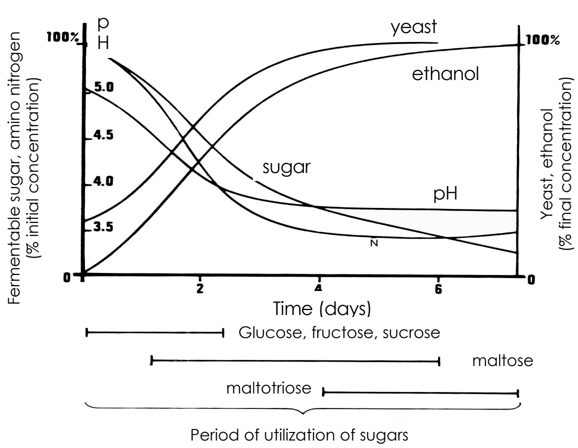
What is yeast?

Single celled fungus→ important to keep them alive and happy!



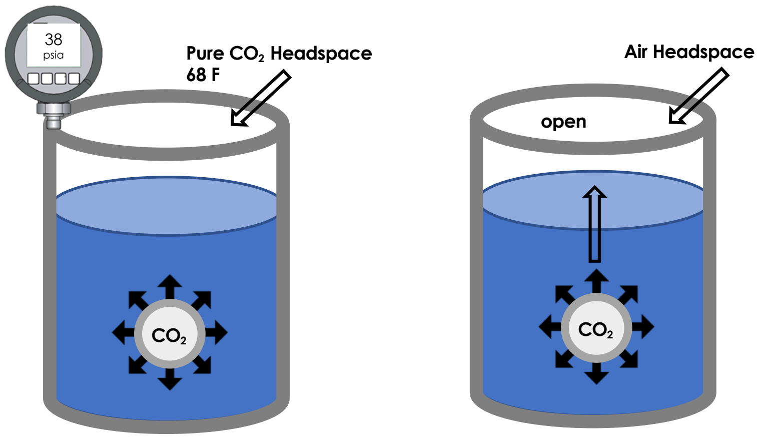


Progress of a typical fermentation



Sugar		+ amino acid	=	yeast growth		+ ethanol		+ CO_2	+	energy
100lbs	+	0.5lbs	~	5lbs	+	48.8 lbs	+	46.8 lbs	+	90,500 KJ

Carbonation



3 volumes ~ 6 g/L at equilibrium

~ 0 g/L at equilibrium

CO_2 Calculation

Sugar		+ amino acid	=	yeast growth		+ ethanol		+ CO_2	+	energy
100lbs	+	0.5lbs	~	5lbs	+	48.8 lbs	+	46.8 lbs	+	90,500 KJ

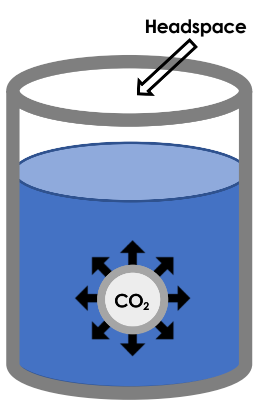
Carbon Dioxide is often present to some degree in "still" wine

	Pressure	~ CO_2 @ 20°C	EU Excise Duty
Still	< 1 bar	<2 g/l	Still
Semi Sparkling	1 to 2.5 bar	2 to 5 g/l	Still
Sparkling	3 bar +	> 6 g/l	Sparkling

- Highly implicated in the still wine flavor profile.
- Results in slightly elevated acidity.
- "A bit of CO_2 helps to preserve the wine a little, so you can lower sulphur dioxide (SO_2) levels fractionally."
- CO_2 becomes perceptible to the human palate at around 1g/L as a slight spritz on the tongue,
- At around 2g/L wine is legally semi-sparkling (see above).

[1]Geoff Taylor, Corkwise writter

Source: Wine and Spirit Trade Association



How to Carbonate

- Traditional
- Forced
- Charmat

Yeast removal and bottling

Traditional **Forced** **Charmat**

Traditional
Pros:
Provides the perceived highest quality sparkling wine products

Cons:
Labor intensive
Long maturation period ~ 6 months to 5 years

Forced
Pros:
Can decrease the wine temperature or apply higher pressures to get faster/higher desired carbonation levels

Easy to receive desired carbonation level

Inexpensive and quick ~ 2-3 days

Cons:
Requires CO_2 tank

Associated with a lack of quality

Charmat
Pros:
Potential unique characteristics with muscadine grape wines

Shorter aging & less labor required than traditional method

Larger quantities produced

Cons:
Require extra step: Filtering

Temperature restricted for yeast reproduction

Yeast may cause off flavors if not properly filtered

Sulfites or other antimicrobials in wines will inhibit this process

Packing

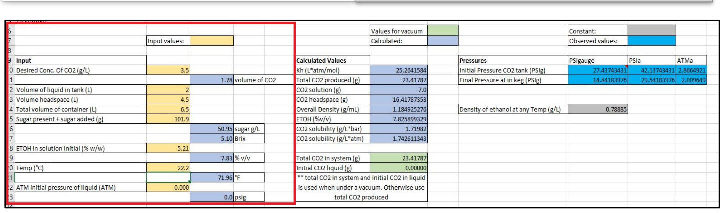
“Champagne pressure, nothing to play with.”.

The pressure in a champagne bottle is typically between 70 and **90 pounds** per square inch.

[1]USA Today, 20 February 2002

Current Work:

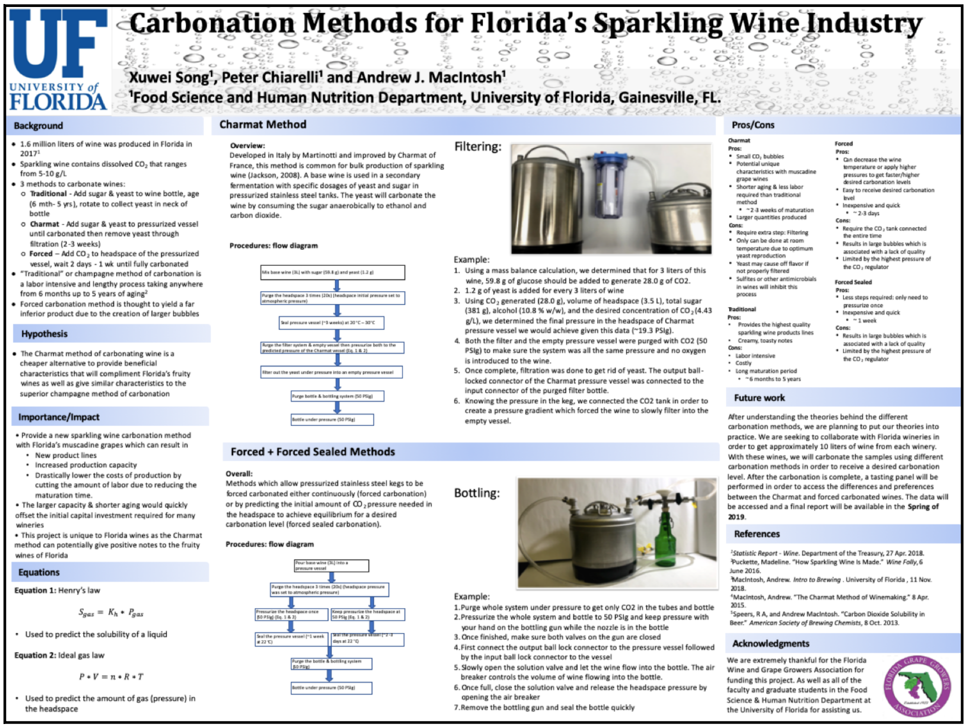
- Florida Sparkling Wine Using The “Charmat” Method.



	Input values:		
Input			
Desired Conc. Of CO2 (g/L)	3.5		
		1.78	volume of CO2
Volume of liquid in tank (L)	2		
Volume headspace (L)	4.5		
Total volume of container (L)	6.5		
Sugar present + sugar added (g)	101.9		
		50.95	sugar g/L
		5.10	Brix
ETOH in solution initial (% w/w)	5.21		
		7.83	% v/v
Temp (°C)	22.2		
		71.96	°F
ATM initial pressure of liquid (ATM)	0.000		
		0.0	psig

Values for vacuum	
Calculated:	
Calculated Values	
Kh (L*atm/mol)	25.2641584
Total CO2 produced (g)	23.41787
CO2 solution (g)	7.0
CO2 headspace (g)	16.41787353
Overall Density (g/mL)	1.184925276
ETOH (%v/v)	7.825899329
CO2 solubility (g/L*bar)	1.71982
CO2 solubility (g/L*atm)	1.742611343
Total CO2 in system (g)	23.41787
Initial CO2 liquid (g)	0.00000
** total CO2 in system and initial CO2 in liquid is used when under a vacuum. Otherwise use total CO2 produced	

	Constant:		
	Observed values:		
Pressures	PSIgauge	PSIa	ATMa
Initial Pressure CO2 tank (PSIg)	27.43743431	42.13743431	2.8664921
Final Pressure at in keg (PSIg)	14.84183976	29.54183976	2.009649
Density of ethanol at any Temp (g/L)	0.78885		



Carbonation Methods for Florida's Sparkling Wine Industry

Xuwei Song[1], Peter Chiarelli[1] and Andrew J. MacIntosh[1]
[1]Food Science and Human Nutrition Department, University of Florida, Gainesville, FL.

Background

- 1.6 million liters of wine was produced in Florida in 2017[1]
- Sparkling wine contains dissolved CO_2 that ranges from 5-10 g/L
- 3 methods to carbonate wines:
  - **Traditional** - Add sugar & yeast to wine bottle, age (6 mth- 5 yrs), rotate to collect yeast in neck of bottle
  - **Charmat** - Add sugar & yeast to pressurized vessel until carbonated then remove yeast through filtration (2-3 weeks)
  - **Forced** – Add CO_2 to headspace of the pressurized vessel, wait 2 days - 1 wk until fully carbonated
- "Traditional" or champagne method of carbonation is a labor intensive and lengthy process taking anywhere from 6 months up to 5 years of aging[2]
- Forced carbonation method is thought to yield a far inferior product due to the creation of larger bubbles

Hypothesis

- The Charmat method of carbonating wine is a cheaper alternative to provide beneficial characteristics that will compliment Florida's fruity wines as well as give similar characteristics to the superior champagne method of carbonation

Importance/Impact

- Provide a new sparkling wine carbonation method with Florida's muscadine grapes which can result in
  - New product lines
  - Increased production capacity
  - Drastically lower the costs of production by cutting the amount of labor due to reducing the maturation time.
- The larger capacity & shorter aging would quickly offset the initial capital investment required for many wineries
- This project is unique to Florida wines as the Charmat method can potentially give positive notes to the fruity wines of Florida

Equations

Equation 1: Henry's law

$$S_{gas} = K_h * P_{gas}$$

- Used to predict the solubility of a liquid

Equation 2: Ideal gas law

$$P * V = n * R * T$$

- Used to predict the amount of gas (pressure) in the headspace

Charmat Method

Overview:
Developed in Italy by Martinotti and improved by Charmat of France, this method is common for bulk production of sparkling wine (Jackson, 2008). A base wine is used in a secondary fermentation with specific dosages of yeast and sugar in pressurized stainless steel tanks. The yeast will carbonate the wine by consuming the sugar anaerobically to ethanol and carbon dioxide.

Procedures: flow diagram

Mix base wine (3L) with sugar (59.8 g) and yeast (1.2 g) → Purge the headspace 3 times (20s) (headspace initial pressure set to atmospheric pressure) → Seal pressure vessel (~3 weeks) at 20 °C – 30 °C → Purge the filter system & empty vessel then pressurize both to the predicted pressure of the Charmat vessel (Eq. 1 & 2) → Filter out the yeast under pressure into an empty pressure vessel → Purge bottle & bottling system (50 PSIg) → Bottle under pressure (50 PSIg)

Filtering:

Example:
1. Using a mass balance calculation, we determined that for 3 liters of this wine, 59.8 g of glucose should be added to generate 28.0 g of CO2.
2. 1.2 g of yeast is added for every 3 liters of wine
3. Using CO_2 generated (28.0 g), volume of headspace (3.5 L), total sugar (381 g), alcohol (10.8 % w/w), and the desired concentration of CO_2 (4.43 g/L), we determined the final pressure in the headspace of Charmat pressure vessel we would achieve given this data (~19.3 PSIg).
4. Both the filter and the empty pressure vessel were purged with CO2 (50 PSIg) to make sure the system was all the same pressure and no oxygen is introduced to the wine.
5. Once complete, filtration was done to get rid of yeast. The output ball-locked connector of the Charmat pressure vessel was connected to the input connector of the purged filter bottle.
6. Knowing the pressure in the keg, we connected the CO2 tank in order to create a pressure gradient which forced the wine to slowly filter into the empty vessel.

Forced + Forced Sealed Methods

Overall:
Methods which allow pressurized stainless steel kegs to be forced carbonated either continuously (forced carbonation) or by predicting the initial amount of CO_2 pressure needed in the headspace to achieve equilibrium for a desired carbonation level (forced sealed carbonation).

Procedures: flow diagram

Pour base wine (3L) into a pressure vessel → Purge the headspace 3 times (20s) (headspace pressure was set to atmospheric pressure) → [Pressurize the headspace once (50 PSIg) (Eq. 1 & 2) → Seal the pressure vessel (~1 week at 22 °C)] / [Keep pressurize the headspace at 50 PSIg (Eq. 1 & 2) → Seal the pressure vessel (~2-3 days at 22 °C)] → Purge the bottle & bottling system (50 PSIg) → Bottle under pressure (50 PSIg)

Bottling:

Example:
1. Purge whole system under pressure to get only CO2 in the tubes and bottle
2. Pressurize the whole system and bottle to 50 PSIg and keep pressure with your hand on the bottling gun while the nozzle is in the bottle
3. Once finished, make sure both valves on the gun are closed
4. First connect the output ball lock connector to the pressure vessel followed by the input ball lock connector to the vessel
5. Slowly open the solution valve and let the wine flow into the bottle. The air breaker controls the volume of wine flowing into the bottle.
6. Once full, close the solution valve and release the headspace pressure by opening the air breaker
7. Remove the bottling gun and seal the bottle quickly

Pros/Cons

Charmat
Pros:
- Small CO_2 bubbles
- Potential unique characteristics with muscadine grape wines
- Shorter aging & less labor required than traditional method
  - ~2-3 weeks of maturation
- Larger quantities produced

Cons:
- Require extra step: Filtering
- Only can be done at room temperature due to optimum yeast reproduction
- Yeast may cause off flavor if not properly filtered
- Sulfites or other antimicrobials in wines will inhibit this process

Traditional
Pros:
- Provides the highest quality sparkling wine products lines
- Creamy, toasty notes

Cons:
- Labor intensive
- Costly
- Long maturation period
  - ~6 months to 5 years

Forced
Pros:
- Can decrease the wine temperature or apply higher pressures to get faster/higher desired carbonation levels
- Easy to receive desired carbonation level
- Inexpensive and quick
  - ~2-3 days

Cons:
- Require the CO_2 tank connected the entire time
- Results in large bubbles which is associated with a lack of quality
- Limited by the highest pressure of the CO_2 regulator

Forced Sealed
Pros:
- Less steps required: only need to pressurize once
- Inexpensive and quick
  - ~1 week

Cons:
- Results in large bubbles which is associated with a lack of quality
- Limited by the highest pressure of the CO_2 regulator

Future work

After understanding the theories behind the different carbonation methods, we are planning to put our theories into practice. We are seeking to collaborate with Florida wineries in order to get approximately 10 liters of wine from each winery. With these wines, we will carbonate the samples using different carbonation methods in order to receive a desired carbonation level. After the carbonation is complete, a tasting panel will be performed in order to access the differences and preferences between the Charmat and forced carbonated wines. The data will be accessed and a final report will be available in the **Spring of 2019**.

References

[1]*Statistic Report - Wine*. Department of the Treasury, 27 Apr. 2018.
[2]Puckette, Madeline. "How Sparkling Wine Is Made." *Wine Folly*, 6 June 2016.
[3]MacIntosh, Andrew. *Intro to Brewing*. University of Florida, 11 Nov. 2018.
[4]MacIntosh, Andrew. "The Charmat Method of Winemaking." 8 Apr. 2015.
[5]Speers, R A, and Andrew MacIntosh. "Carbon Dioxide Solubility in Beer." *American Society of Brewing Chemists*, 8 Oct. 2013.

Acknowledgments

We are extremely thankful for the Florida Wine and Grape Growers Association for funding this project. As well as all of the faculty and graduate students in the Food Science & Human Nutrition Department at the University of Florida for assisting us.

Grant Examined Sparkling FL Wine -Conclusions-

Methods to carbonate Florida wines using both the forced and Charmat methods were developed

Developed tools that allow users to predict CO_2 pressure required

There was a significant difference between the forced and Charmat sparkled wine in a triangle test - individuals could discern the difference between wine carbonated using the two methods (at equal sugar/ethanol/carbonation levels)

However, there was no significant difference for whether the forced or the Charmat method was preferred over the other

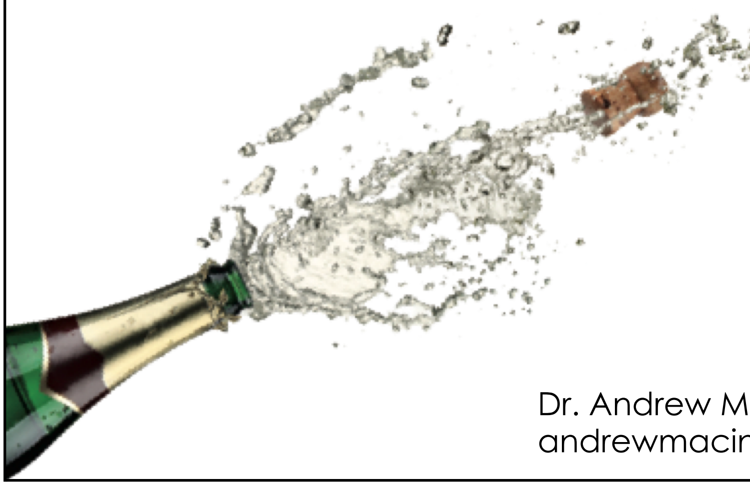
Current Work:

- Carbonating Florida Wines

Objective: To assist the Florida wine industry to produce, evaluate, and educate individuals and companies to implement new sparkling wine methods, resulting in novel product lines and increased production capacity of sparkling wine for the ever-growing Florida wine industry.

Dr. Andrew MacIntosh
andrewmacintosh@ufl.edu

Questions



Dr. Andrew MacIntosh
andrewmacintosh@ufl.edu

Pressure/Solubility Calculation

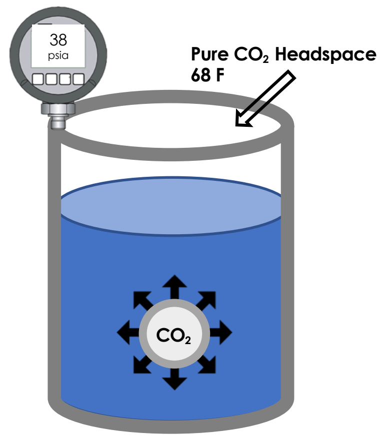
Solubility within a liquid is dictated by Henry's Law:

$$p = k_{\mathrm{H}}\, c$$

equation:	$K_{\mathrm{H}}^{pc} = \frac{p}{c_{\mathrm{aq}}}$
unit:	$\frac{\mathrm{L \cdot atm}}{\mathrm{mol}}$
O_2	770
H_2	1300
CO_2	29
N_2	1600
He	2700
Ne	2200
Ar	710
CO	1100

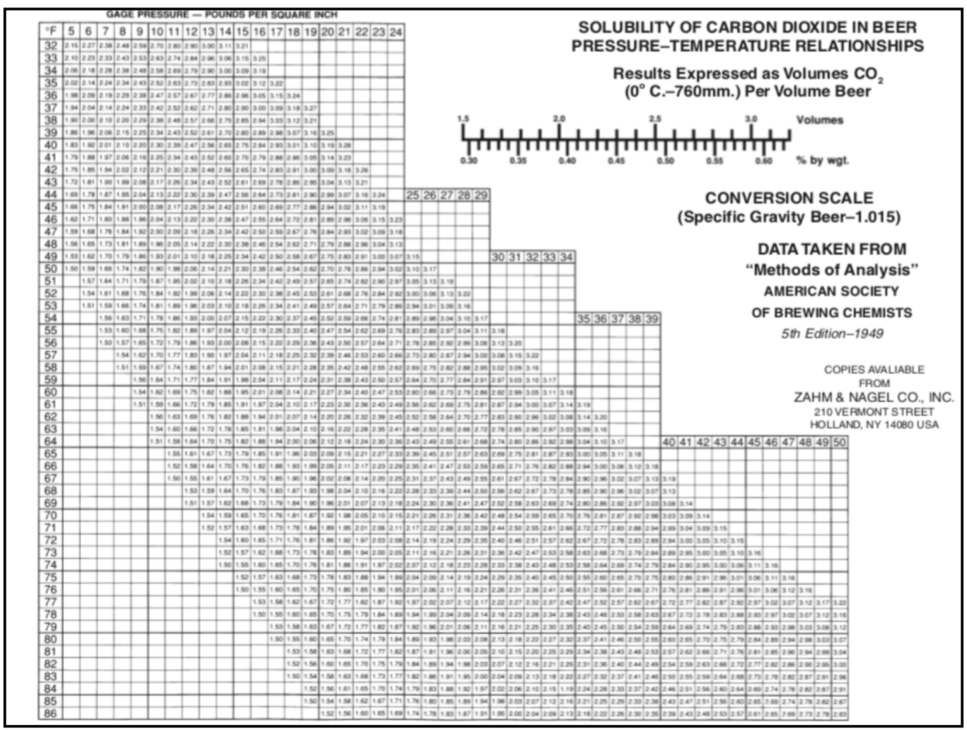
Henry's law constants (gases in water at 298.15 K)*

where
- *p* is the partial pressure of gas, (i.e. ATM)
- *c* is the concentration of the solute (i.e. mol/L)
- k_H is Henry's constant (L ATM/mol).



3 volumes ~ 6 g/L at equilibrium

*Sander, R. (2015), "Compilation of Henry's law constants (version 4.0) for water as solvent", Atmos. Chem. Phys., 15 (8): 4399–4981



Physical Test

- A simple pierce apparatus is typically used to assess pressure and temperature:
- Assumed to be at equilibrium
- CO_2 dissolved determined form chart or equation

Carbonation

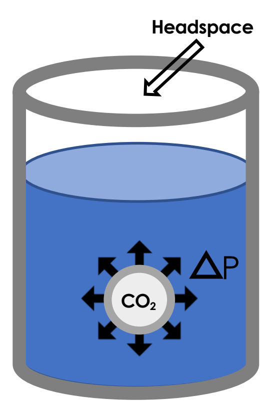
Factors affecting efficiency of forced carbonation:

1. **Bubble size→ smaller is better:**
   - **Smaller bubbles give larger surface area to volume ratio**
   - **Larger pressure difference, inside > outside bubble**
2. **Agitation due to bubble formation → prevents concentration gradient (of CO_2)**

Higher applied pressure + small pore size = smaller bubbles

BUT

if applied pressure is too great, headspace pressure will equilibrate therefore slow CO_2 diffusion in beer



Conditioning

Factors affecting efficiency of forced carbonation:

- **Temperature of beer**
- **Carbonation stone → pore size and material: steel vs. ceramic**

  ****wetting pressure: minimum pressure required to just start carbonation, usually 5-8 psi (34.5-55.2 kPa)**