

Oxygen, Friend and Foe:

Where it comes from, how to test for it and how to
manage

Darren Michaels

darrenm@scottlab.com

509-936-1796 cell



Oxygen is a Friend

- Yeast prefer oxidative states
 - Brownd juice is better for yeast as opposed to antioxidative conditions
- Promotes chemical oxidation of phenols
- Can help with color stabilization
- Can soften tannins
- Can lower the perception of green notes
- Protects against reduction

Oxygen is a Foe

- Excessive growth of spoilage organisms
- Film Yeasts
- Acetobacter
- Makes SO₂ management hard and lowers levels
- Leads to fast degradation of wine post bottling
- Browning, suppressed aromas, oxidized/honey aromas
- Feeds enzymatic browning

Oxygen-Based Faults

- Oxidation signs
 - Whites that are brown, reds that are brickish
 - From nice light yellow to gold to brick
 - Acetaldehyde/aldehydic aromas
 - Reds that are flat- no aroma



Oxygen-Based Aromas

- Whites: fruity to aldehydic (Madeira, Sherry, etc.).
 - Whites known for aging: Hunter Semillon, white burgundies, Loire Chenin Blanc (some in combination with oak)
- Reds may develop complexity, softness (Bordeaux, Cal CS, Barolo, Rioja).
 - Light wines turn brown early, lose fruit, become flat.
- Sweet wines: sugar acts as a preservative and may allow time to develop complexity.
 - Port, Madeira, Setubal, Banyuls, Sauterne, etc.

Enzymatic Browning (mold-affected fruit)

(with thanks to Drew Horton)

- *Polyphenol Oxidase*- sensitive to SO₂
- *Laccase* is an enzyme in molds like *Botrytis*
- Can cause phenolics to convert to *quinones* which form pigmented compounds- Browning!
- Remedy? SO₂ and no O₂, (anaerobic ferment)
- Aggressive SO₂ addition in must
- Bentonite in white juices
- Lower pH's better (retards enzymes)



White Juice: Anaerobic vs Aerobic treatment

- Depending on how the style of wine is preferred
- Anaerobic treatment- Juice fining is recommended
 - Provencial Rose or New Zealand Sauvignon Blanc
 - Hand picked fruit when possible- dry ice in bins
 - Maximizing thiol and esters notes by preventing oxidation
 - SO₂ additions up to 50-60 ppm in juice (or ascorbic acid)
 - Rehydration nutrients highly recommended
- BUT....increases chance of pinking

White Juice: Anaerobic vs Aerobic treatment

- Aerobic Treatment
 - Browning/Adding oxygen/Flotation with air
 - Bitter phenolics can be reduced through oxygen bridging and polymerization
 - With early introduction of oxygen eliminates chance for pinking
 - INOCULATE VERY SOON to prevent attack of microbes

Oxygen and Yeast



- With Oxygen, Yeast are healthier
 - Essential part of sterol production
 - With increased sterol production comes increased cell wall fluidity
 - With increased cell wall fluidity comes better uptake of nutrients, better protection against influences of alcohol
 - Ergosterol is a critical sterol for yeast viability
 - Rehydration nutrients can assist in exosterol and membrane fluidity

Oxygen and Red Ferments

- Red pigments are a natural oxygen scavenger
 - During fermentation oxygen adds can be made to feed the yeasts
 - Racking and Return, Punch-Downs, Pulsair
 - Venturis, Pump over with grates
 - Softens tannins through polymerization
 - Aldehydic bridging can increase color
- Follow recommended steps to acclimate yeast correctly-
 - Non-Sacchromyces such as *Metschnikowia sp.* Gaia should also protect the top of the ferment to control spoilage

Post-Fermentation Storage

- STOP!
- Careful consideration should be made to investing in a dissolved oxygen meter before moving forward
- *Keep Oxygen additions as far away from the bottle as possible*
- The same wine made in a different space will have tremendously different exposures to oxygen- From Tank to Bottle

Post-Fermentation Storage



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Surface to Volume



Gallons per Container

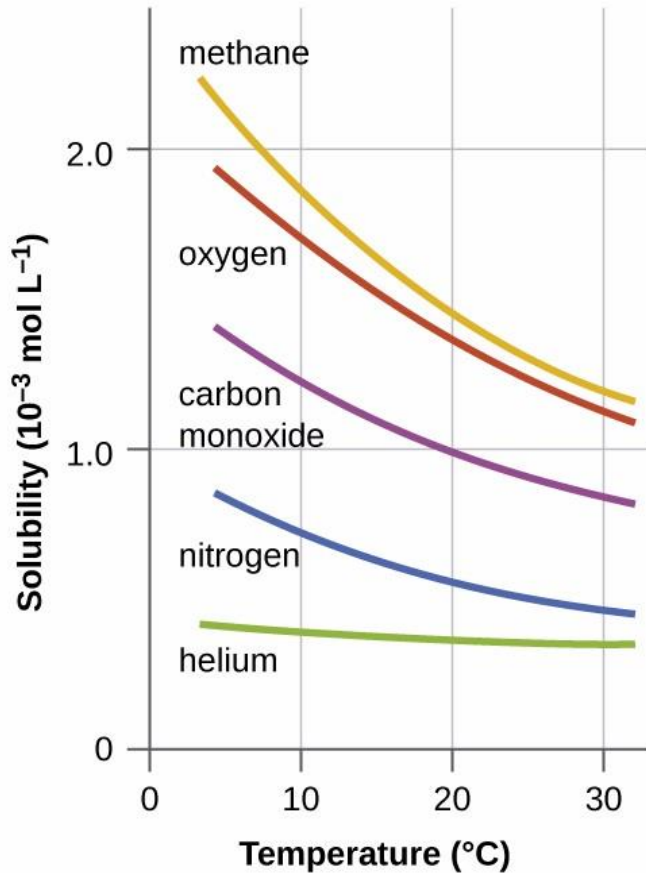
Key: Oxygen Entry Points

- Dissolved Oxygen (thanks Luke)
 - Levels and exposure can vary wildly
 - Handling and processing techniques
 - Temperature

Operation: Wine Transfer	Temperature (°F)	Average mg/L O2 pickup
Bottom Tank Pumping	70	0.5
Bottom Tank Pumping	50	1.3
Splash Racking	n/a	7

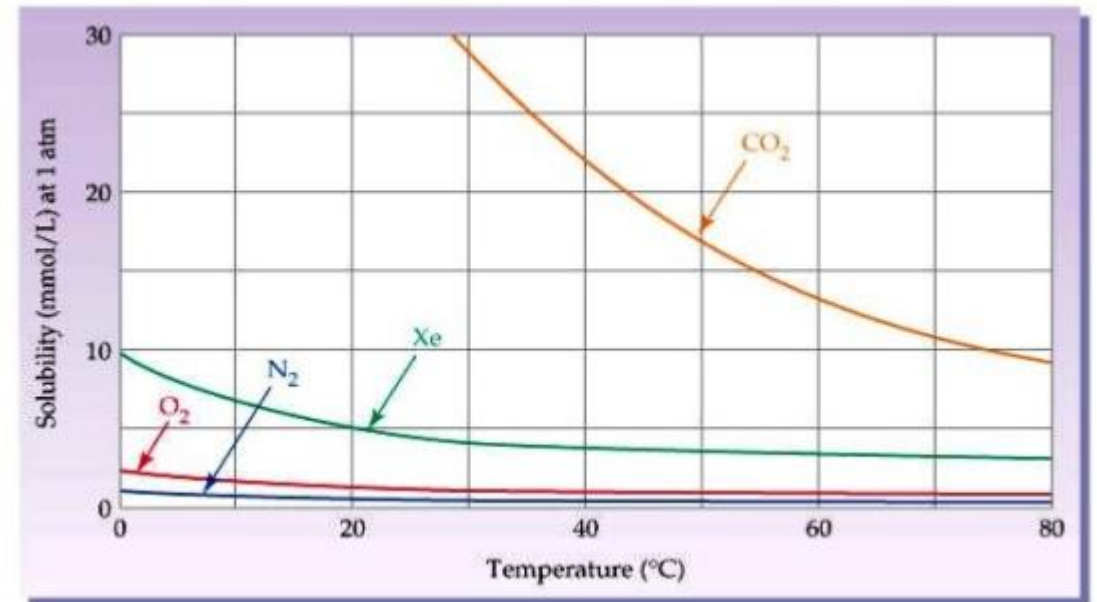
Action in cellar	Dissolved O ₂ (mg/L)
Topping	1
Pumping	1 - 2
Filtration	0.5 - 2.5
Racking	2 - 5
Racking with O ₂	4 - 8
Centrifugation	1.5 - 2.5
Cold stabilization	3.5 - 6
Bottling	0 - 4
Transport (full tank)	0 - 6

Key: Gas Solubility vs Temperature



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SOLUBILITY GRAPH OF GASES IN WATER



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Post-Fermentation: Managing Oxygen

- Oxygen Management Very Critical Post-Fermentation
- Managed by five critical areas:
 - Container/Headspace Management
 - Sulfur dioxide Management
 - Gas Management (Sparging, Nitrogen, Argon, Carbon Dioxide)
 - Lees Management
 - Tannin Management

Container/Headspace Management

- Minimize headspace, no matter what
- Tanks with partial headspace will lead to wine spoilage
- Variable tops: keep gaskets full, keep everything clean
- **Tanks to barrels to kegs to carboys**
- Barrel aging
 - All wines are “Micro-oxygenated” when in barrels
 - Rates of oxygenation depend on barrel construction/wood type
 - Rates also are dependant on tartrate and other soil buildup

Container/Headspace Management

- **CONTROLLING AND MINIMIZING OXIDATION**

- Slow vs. fast oxidation
- Different reaction products created
- Barrel vs. stainless vs. plastic

- New products like GoFermentor-

- One-use collapsible bag
- Push air out



SO₂ Management

- Confirm Dryness and ML complete before SO₂ addition
 - If possible, measure verify glucose+fructose is 1.0 g/L or less
 - Verify malic acid is less than 0.3 g/L
- Sulfur Dioxide has two main functions
 - Anti-microbial (which is pH dependent)
 - Anti-oxidative
- SO₂ doesn't react directly with O₂
 - *SO₂ competes for hydrogen peroxide and prevents aldehyde formation*

SO2 Management

- Initial dosages of SO2 can be high
 - 60-100 ppm addition after all fermentation activity
 - Can lead to higher return on addition- Free sulfur should be measured
 - Don't make adds less than 20ppm ever
- Initially, carbon dioxide will be present in wine to blanket
 - If kept cold, the CO2 will remain for a while
- But as wine warms, it will drop and other factors will be required to protect against oxidation

SO₂ Management

- Free Sulfur MAINTENANCE is easier than fixing oxygen
 - Semi-regular testing is key
 - Free sulfur should be >15-20 ppm to help protect against oxygen
- SO₂ Management: Add, test, add, test, add, test....
- Molecular SO₂ works against microbes
 - But is pH dependent (see next slide)
 - Low pH wines need less to fight microbes but...
 - Might need more to fight cold temperature uptake of oxygen
- Aeration oxidation or Vinmetrica

0.5% to 0.8% Molecular: Anti-microbial

pH	SO ₂											
	8	14	20	27	35	42	50	60	75	90	110	130
	em: High Range 40-----60 Low Range											
2.9	7	11	(ppm)									
3.0	8	13										
3.1		10	16									
3.2		13	21									
3.3			16	26								
3.4			20	32								
3.5				25	39							
3.6				31	49							
3.7					39	63						
3.8						49	79					
3.9							62	98				
4.0								78	123			

Free SO₂ goals in GRAY

Thanks
Drew!

Gas Management: Purging and Sparging

- Move “anaerobically” – move without adding oxygen
- That means purging and sparging
- Purge with dry ice (CO₂), nitrogen, argon, or a mix
 - It takes a lot of gas to sparge a tank- multiples volumes to move oxygen percent from atmospheric (21%) to less than 1%. That’s a lot of gas!
- Measure measure measure
- Meters/probes \$500-\$2000

Post-fermentation: Purging

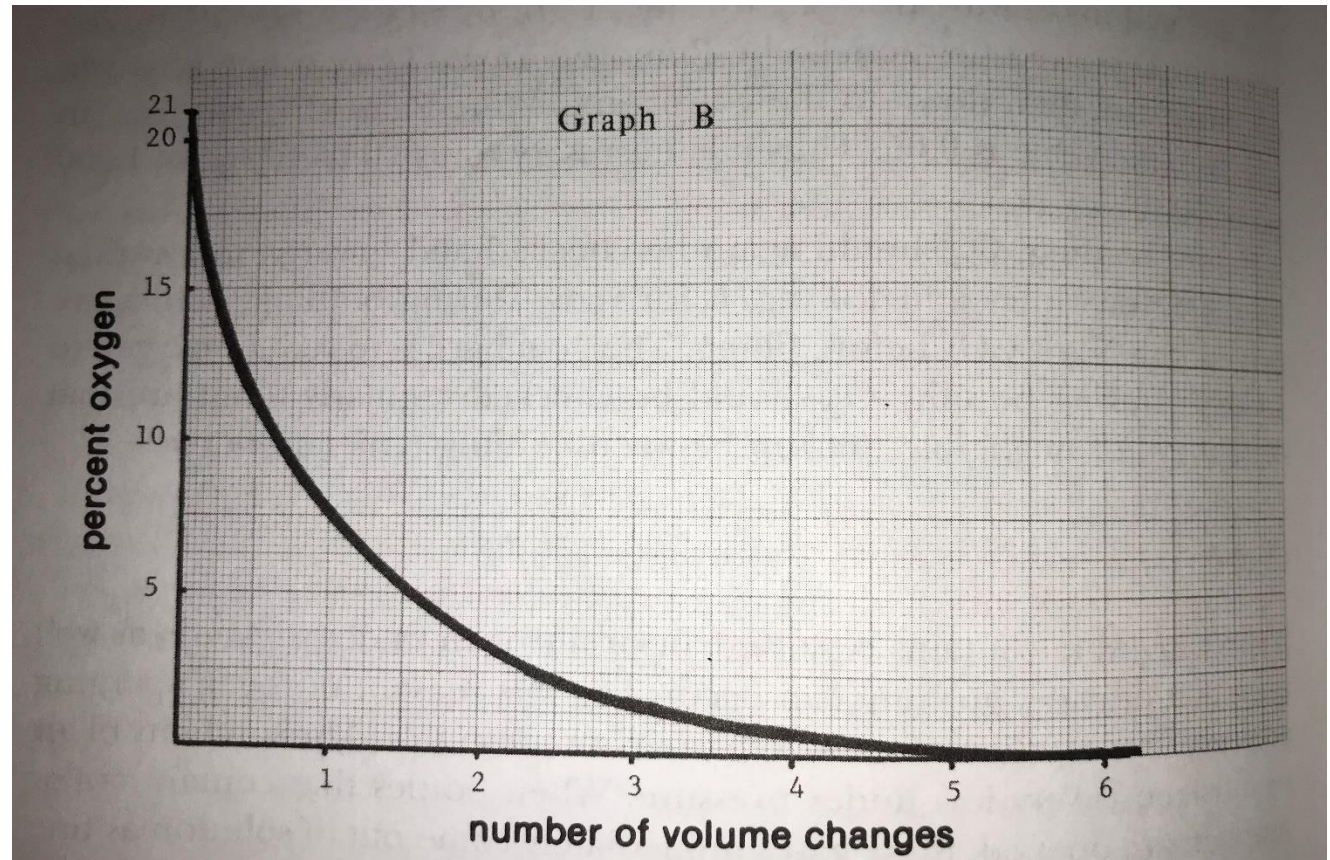
- Displacement of air in containers; not for long-term storage.
 - 3.25 volume changes to 1% O₂; 5.0 changes for <0.5%.
 - Use gas to push wine during transfers (Bulldog Pup).
 - Flush lines with gas before transfer.
 - Fill space to be pumped into and displace air in container pumping from.
 - Nitrogen is preferred sparging gas.

Post-fermentation: Purging a tank

Zoeckling et. Al
*Wine Analysis and
Production*

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To move oxygen in 1000 gal
tank from atmospheric to
1% oxygen:
7.48 gal/cu. ft
133.7 cu. Ft
3.25 times 133.7 cu ft Or
434 cu ft
Two tanks of N₂



Gas Management



Inline Sparging



Dissolved Oxygen Monitoring

**Dissolved O₂
In wine**

*Measuring range:
0 to 50 mg.L⁻¹*



**Atmospheric O₂
In empty vessel**



Thermo-Orion A223—single parameter, only does DO.

Thermo-Orion A326—DO, pH and conductivity.

Gas Management: Sparging a Wine

- If cold temperature, residual CO₂ will remain until it warms up. You can use that as the initial blanket.
- Or you can sparge DO with nitrogen (N₂) before first SO₂ addition
 - Use high-purity N₂.
 - Sparging stone (smaller holes more efficient)
- Approx. 0.045 ft³ gas/gal. needed to drop DO 50% (Zoecklein et al).
- The lower the DO, the harder it is to pull out.

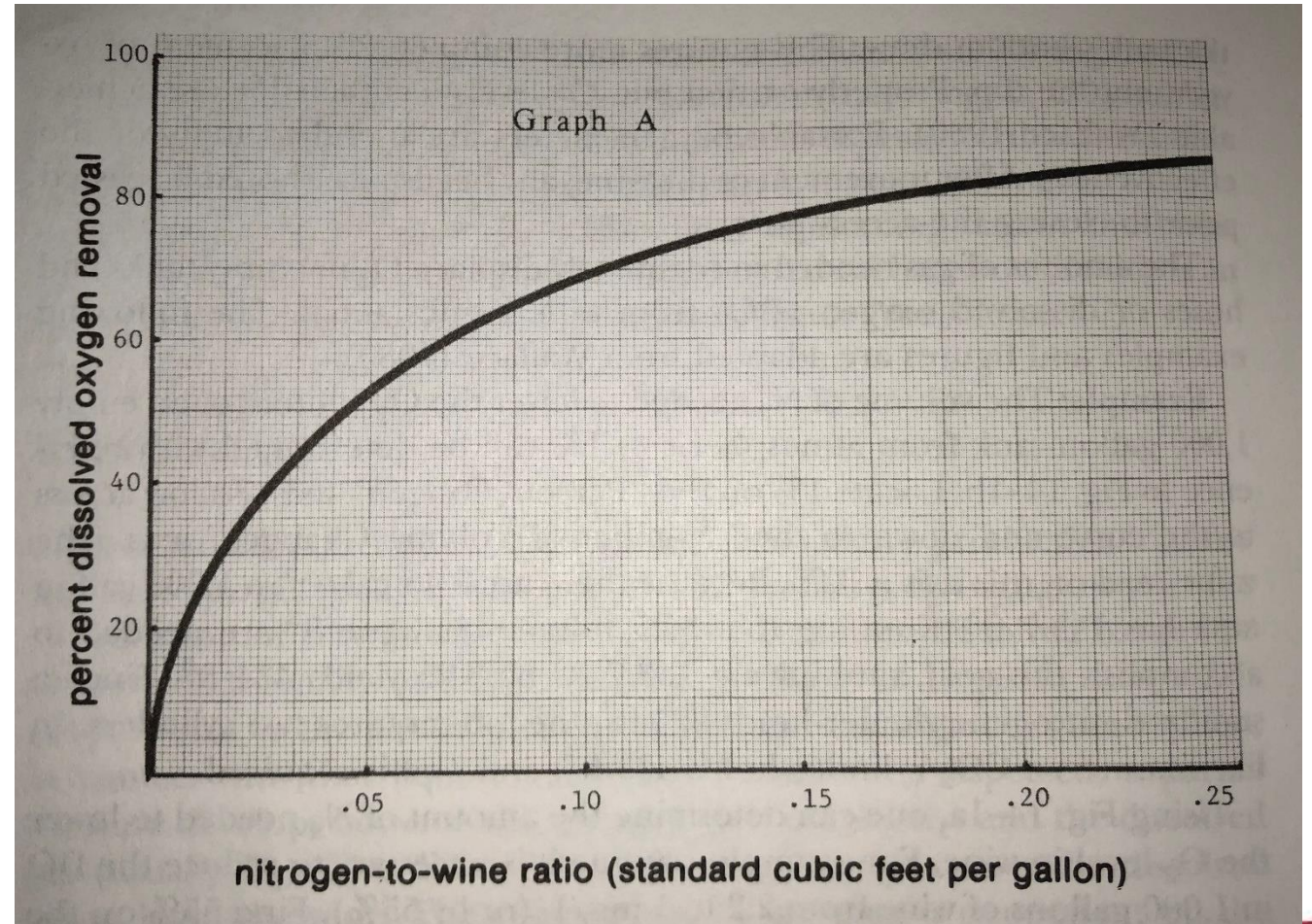
Gas Management

Zockline et. al *Wine Analysis and Production*

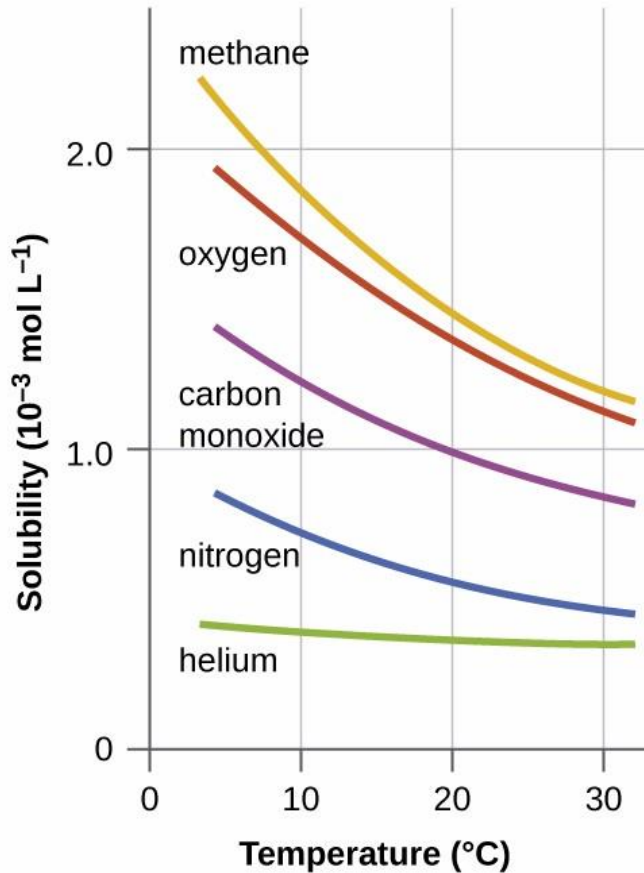
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Amount of Nitrogen required to remove percentage of oxygen from wine

For 1000 gals to move oxygen 2.2 ppm to 1.0 ppm, it would take 50 cubic ft

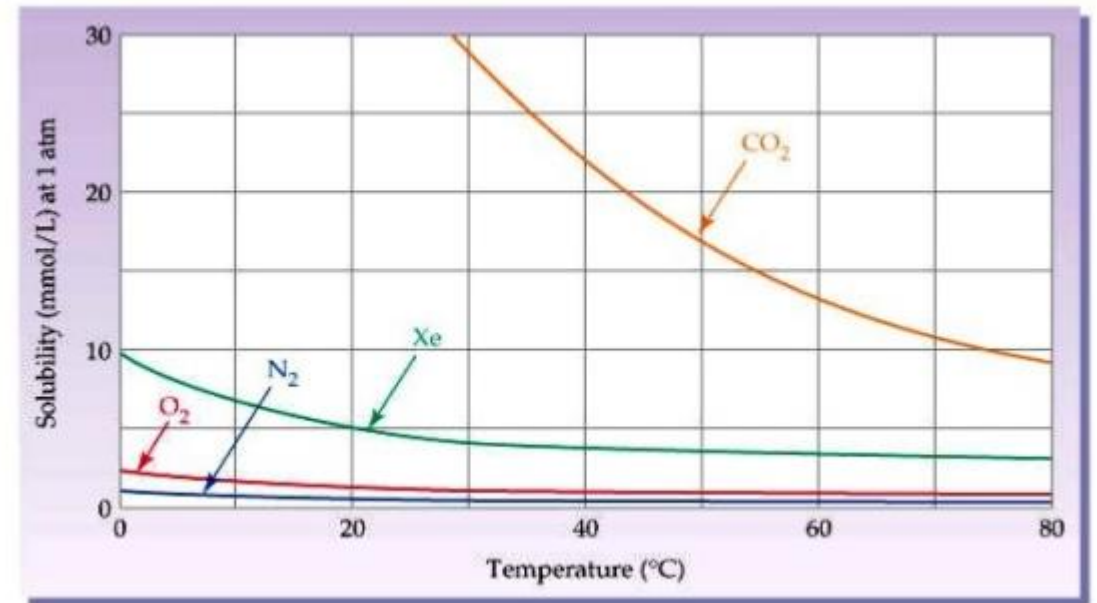


Repeat: Gas Solubility vs Temperature



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SOLUBILITY GRAPH OF GASES IN WATER



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Gas Management: Sparging Wine

- Gas (argon, nitrogen, CO₂, dry ice)
- Standard K-tank volumes (approx. 100# tare weight):
 - Nitrogen: ~1675 gal (224-230 ft³)
 - Argon: ~1907 gal (245-255 ft³)
 - CO₂: ~3253 gal (435 ft³) or 50 lbs.
- Argon and CO₂ heavier than air; nitrogen lighter. CO₂ most soluble
 - One cubic ft. of gas (ft³) = 7.48 gal. gas.

General Guidelines

- Sparge 58-68 F at 1 to 2 atm of the gas
 - 0.1-0.3 liters of gas per liter of wine
- Headspace above wine- keep at 0.5% Oxygen if possible
 - Sparge tanks or lines 3-7 volumes
- Use CO₂/Nitrogen mix for whites
- Use Nitrogen for reds
- Use CO₂ or Nitrogen or a mix of both for purging tanks
- Measure with meter or a lit match (if it can't stay lit, good!)

Post-fermentation: Sparging



Crush 2 Cellar



Gas Management: Barrel Aging

- Tips for Oxygen Management in Barrels:
 - Topping wine should be low DO, and have adequate SO₂
 - Should also be “clean” wine w/o microbial populations
 - Based on experience, a winemaker may want to add SO₂ during topping
 - Prior to filling barrel, inert headspace with Ar, CO₂, N₂
 - Alternatively, once filled, sparging with high purity N₂ can “rip” DO down
 - Install gas port in bung to inert headspace prior to opening barrel
 - w/o this, O₂ rich air will rush into barrel when bung is pulled

Gas Management: Bottling

- Zoecklein et al (Wine Analysis and Production) recommended DO levels:
 - Reds: <1.0 mg/L
 - Whites: <0.5 mg/L
- Levels this low can only be achieved using high purity nitrogen
- Typical levels before bottling are 2 to 8mg/L
- Pickup is highest at startup!

Gas Management: Bottling

- White wines and some lighter reds like carbon dioxide
 - Whites like a little CO₂, 0.8 – 1.0 g/L
 - Light reds like 0.5-0.6 g/L
 - Use Carbodoseur to verify CO₂ levels
- Use a mixture of CO₂ and Nitrogen (3:1 CO₂ to Nitrogen)
- Purge all pre-bottling containers of oxygen. For whites you can use carbon dioxide
- Measure post-bottling to verify DO is still low

Gas Management: Bottling

- Why are we so concerned with DO at bottling?
 - “Bottle Shock”
 - This can be minimized by ensuring low DO, using a low O₂ pickup filler, and a proper vacuum corks/ inerted screwcapping
 - Post Bottling Oxidation
 - Development of oxidative flavors
 - Browning, color deterioration
 - Shorter shelf life

Gas Management: Bottling

- Post Bottling Oxidation
 - Reduction of SO₂
 - *1 ppm of DO₂ will consume 4 ppm FSO₂*
 - By measuring your FSO₂ drop, you know how much O₂ you added
 - Can also help feed spoilage microbes such as *Acetobacter* and *Brettanomyces*
 - With oxygen, Brett produces much more acetic acid as opposed to alcohol

Gas Management: Closure Choice

- Screwcaps
 - Applied Correctly, consistent gas transfer
 - Need to manage bottle headspace
 - Do screwcaps really cause reduction?



Gas Management: Closure Choice

- Corks
 - Natural (variability?)
 - Grades: generally, higher grade = denser = less O₂ = longer shelf life
 - O₂ slowly leaks into the wine from inside the cork (6 months to a year)
 - 1+1's, Synthetic, Agglomerated
 - Best for quick through market wines

Lees Management

- Lees and SIY usage
 - Lees Longevity
 - PURE-LEES LONGEVITY™ O₂ consumption rate for a dose rate at 40 g/hL is 1.7 mg/L dissolved oxygen. If the dose rate is doubled, the level of O₂ consumption also increases. Consumption rate by this SIY yeast = 0.7 mg/L O₂ per hour
- Use Lallzyme MMX enzyme to make your own!



Tannin Management

- Tannins are oxygen scavengers
- Regular small adjustments with targeted enological tannins can help shift a wines redox
- Assists in SO2 and Gas Management
- Later additions require trials



Managing Oxygen Final Take-aways

- *Keep oxygen as far away as the bottle as possible!*
- Gas solubility is temperature dependent! Don't sparge unless up to temperature
- Measure Oxygen with meters if possible
- Close to bottling: Purge tanks and lines when moving wine
- Maintain SO₂ with testing and more adds (no adds less than 20 ppm unless close to bottling).

Thank you!

Darren Michaels
darrenm@scottlab.com
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