

The Science of Beer Brewing

August 4, 2025
NEMC Symposium

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CHEM 1021: Beer Brewing

Chemical and Biochemical Principles

- A new course for non-science majors
- Laboratory Emphasis
- Students excited to enroll!
- Topic of general interest
- Lots of Science!
- Incredible History



College Credit for **BEER?!**

A course for non-science majors about the chemistry and biology of beer brewing

Fall Semester Schedule:

Lecture	MW	11:00am-11:50am
Lab	M	12:30pm-3:30pm



Image: NPR.org

CHEM 1021 Beer Brewing: Chemical and Biochemical Principles

- 🍺 3.0 credit hours
- 🍺 Lecture and lab sections
- 🍺 Beer analysis and brewing
- 🍺 Fulfills science requirements
- 🍺 Field trips to local breweries
- 🍺 No prerequisites
- 🍺 Guest lectures
- 🍺 Now offering 1.0 credit hour lecture-only audit section

Enroll now!

How is beer made?



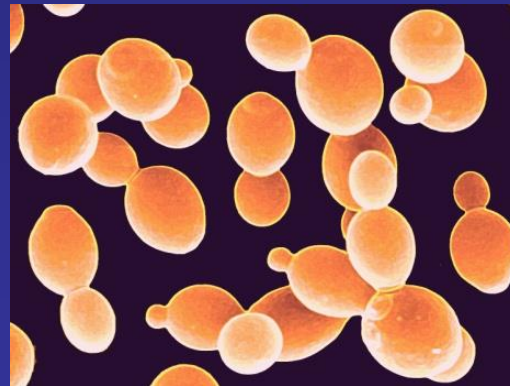
Malt from grain



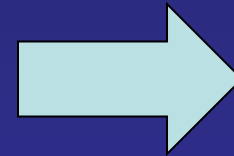
Water



Hops



Yeast



Laboratory Exercises

- 50% online lectures;
- 50% laboratory
- Eight labs in 12 sessions
- Water chemistry
- Beer Brewing
- Analysis
- FIELD TRIP



Lab 5: All Grain Beer Brewing



Pumpkin Ale, Export Porter, Weissbier, Blonde Ale, Marzen, IPA, Brown Ale

Humulone to Isohumulone

α -acids (AA) to iso- α -acids (IAA)

α -acids (AA) in hops



Brewing Process



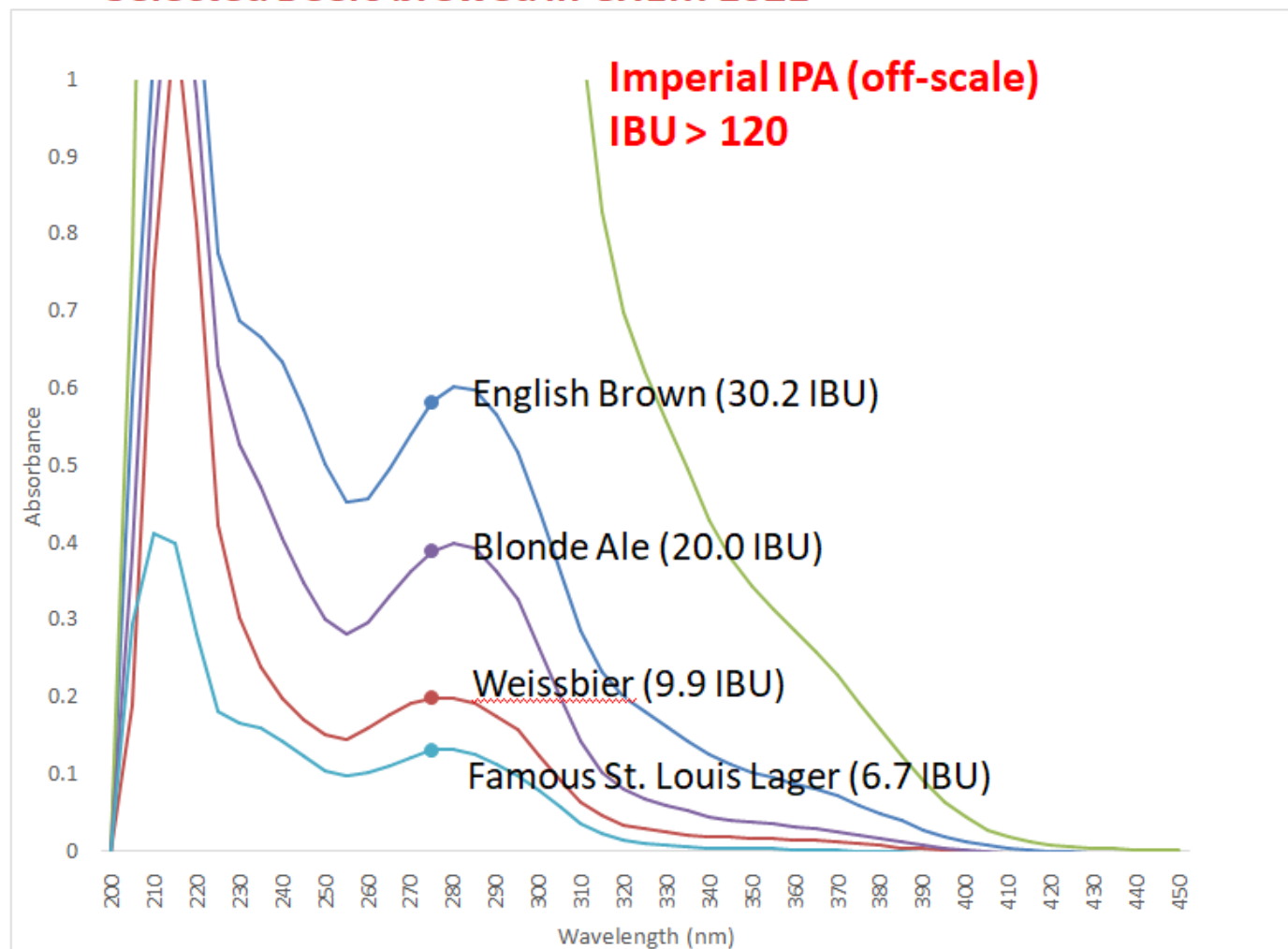
Iso- α -acids (IAA) in beer



- IAA content - Beer Bitterness (IBU)
- IBU range 10 to >100 IBU
- Bitterness due to more than just IAA content!

Lab 6: Spectroscopic Determination of Bitterness

Selected Beers brewed in CHEM 1021



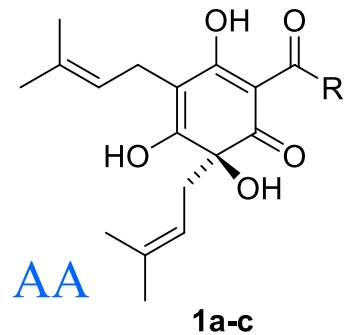
ASBC: 'Beer 23':

Isooctane extract of acidified beer

$$\text{IBU} = \text{Abs}_{275\text{nm}} \times 50$$

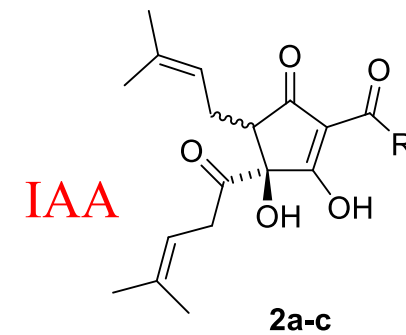
Components of Hops and Beer

Humulones (α -acids)



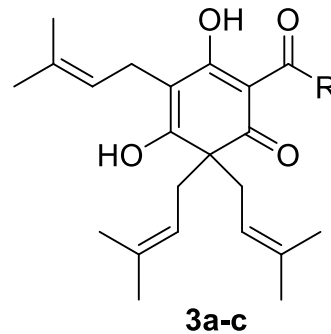
Compd	R	Mw
cohumulone	<i>i</i> -Pr	348
n-humulone	<i>i</i> -Bu	362
adhumulone	<i>sec</i> -Bu	362

Isohumulones (iso- α -acids)

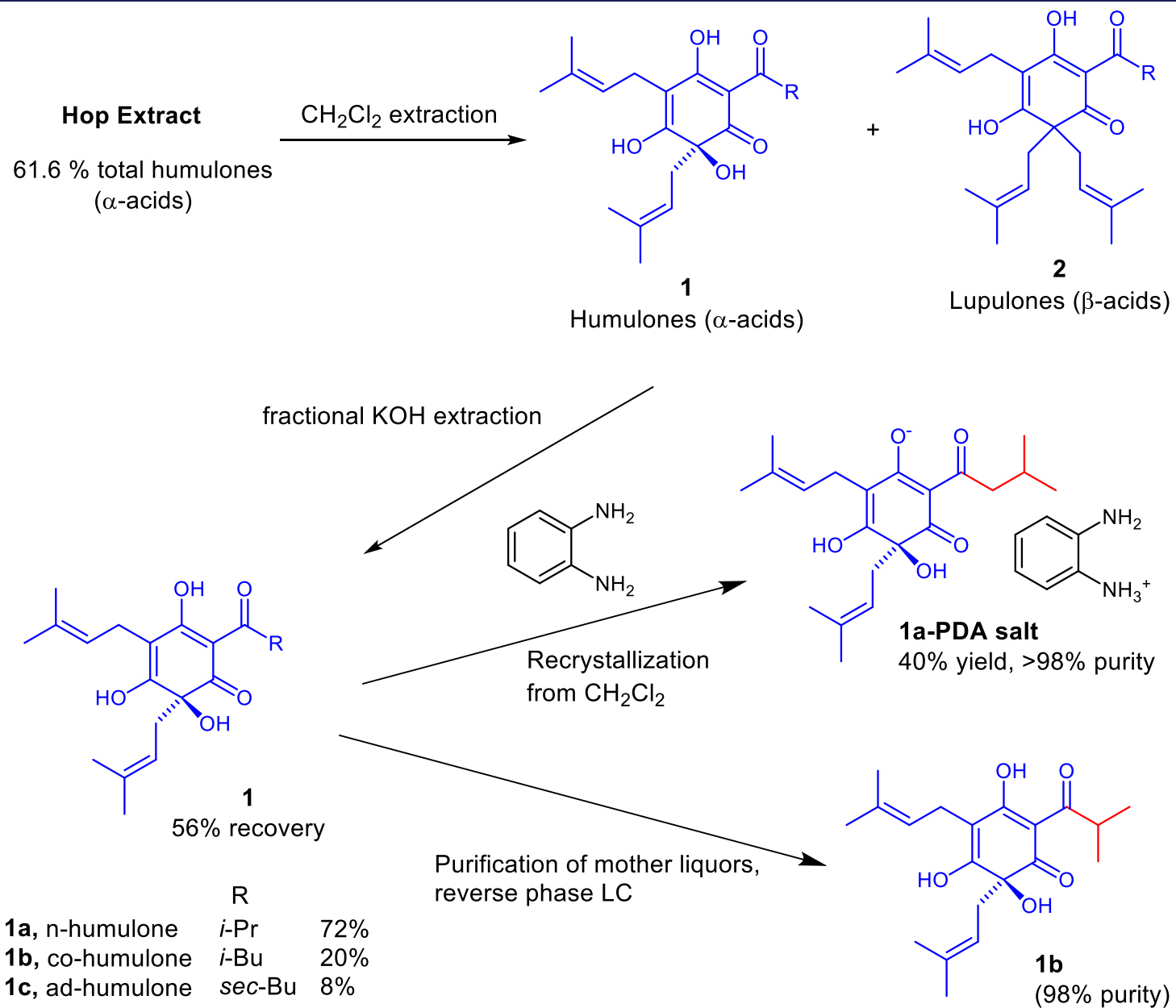


Compd	R	Mw
coisohumulone	<i>i</i> -Pr	348
n-isohumulone	<i>i</i> -Bu	362
adisohumulone	<i>sec</i> -Bu	362

Lupulones (β -acids)

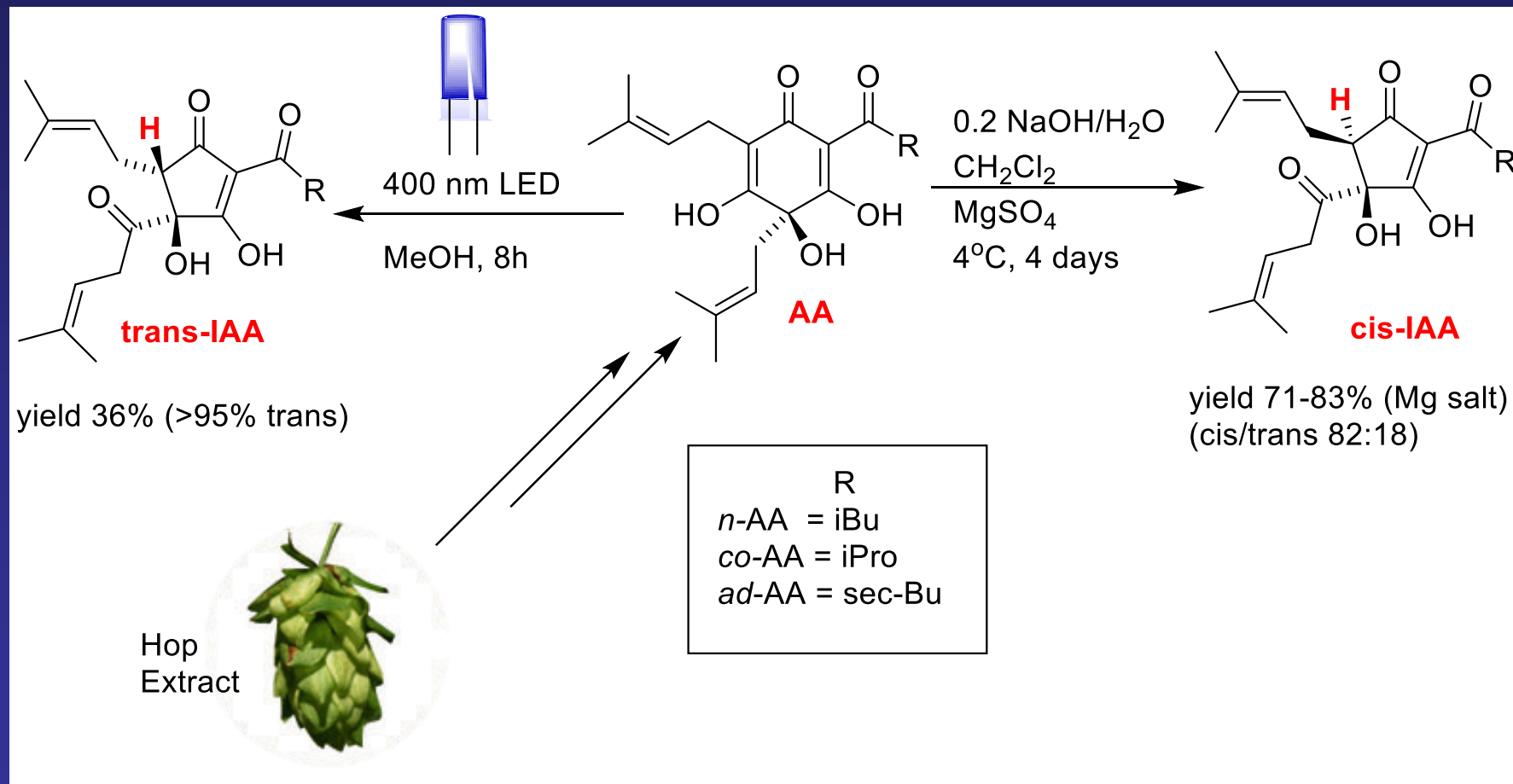


Compd	R	Mw
3a	<i>i</i> -Pr	400
3b	<i>i</i> -Bu	414
3c	<i>sec</i> -Bu	414

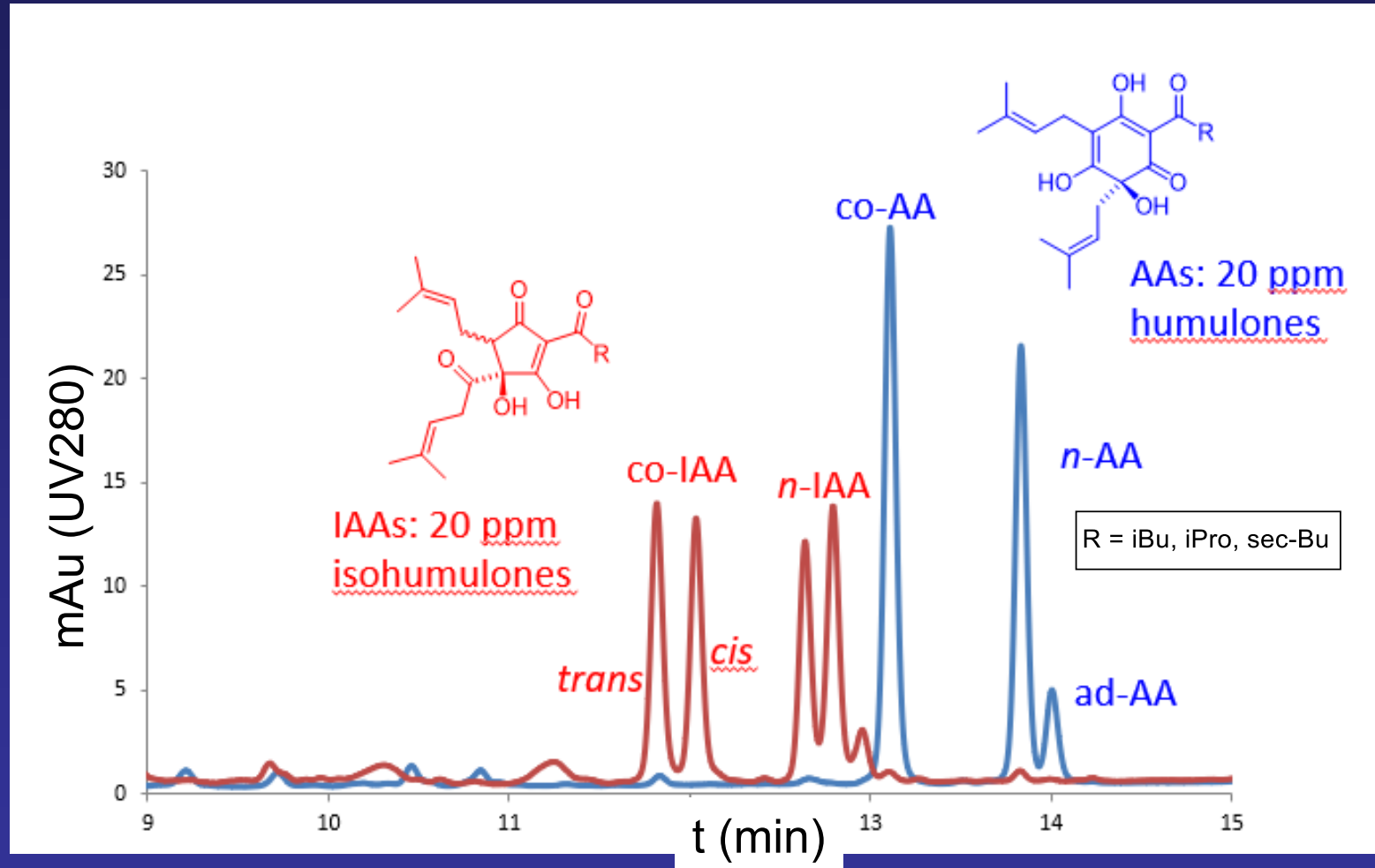


Synthesis of Humulone Standards

cis- and *trans*-isohumulones (IAA)

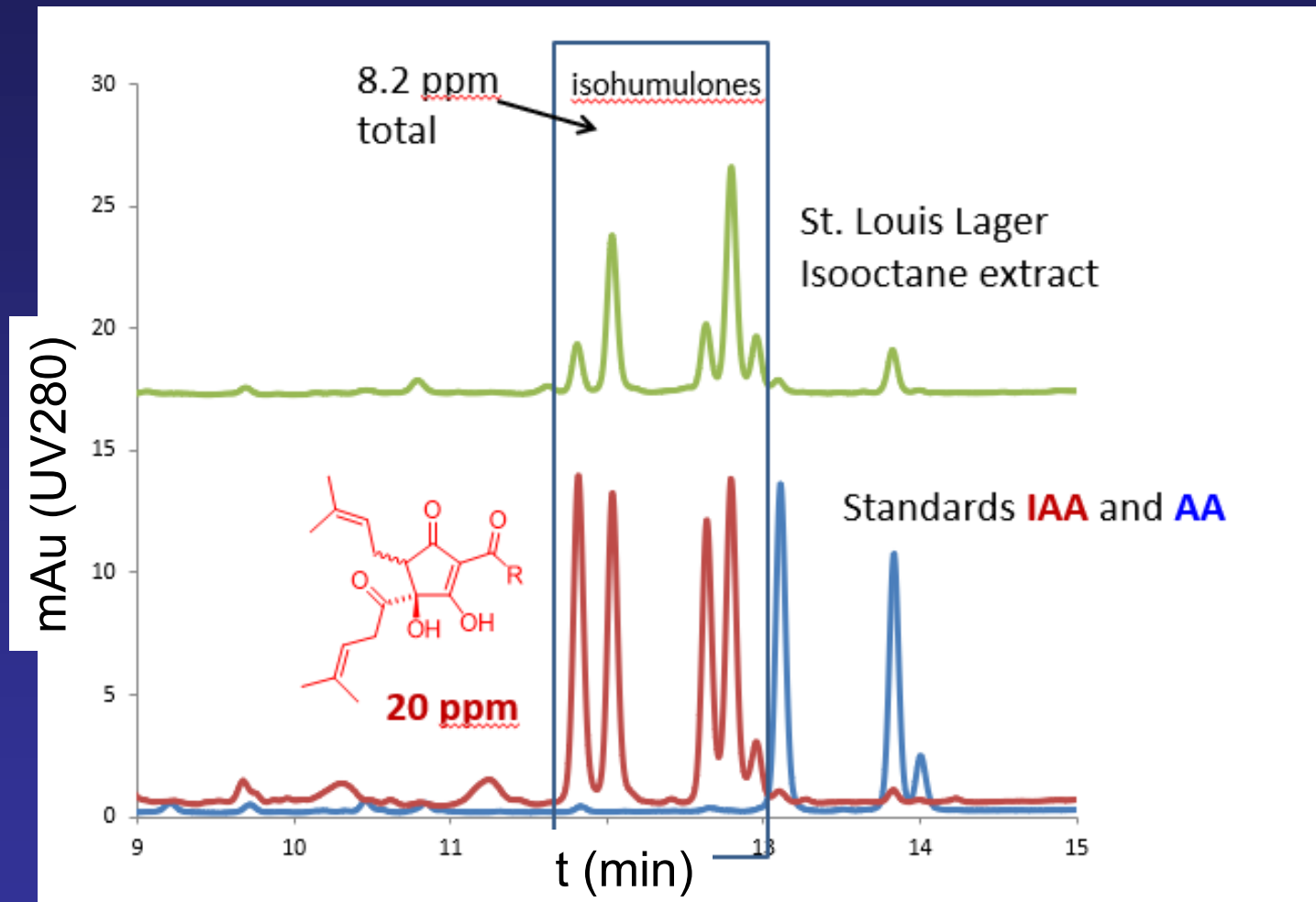


HPLC: Isomerization of Humulones



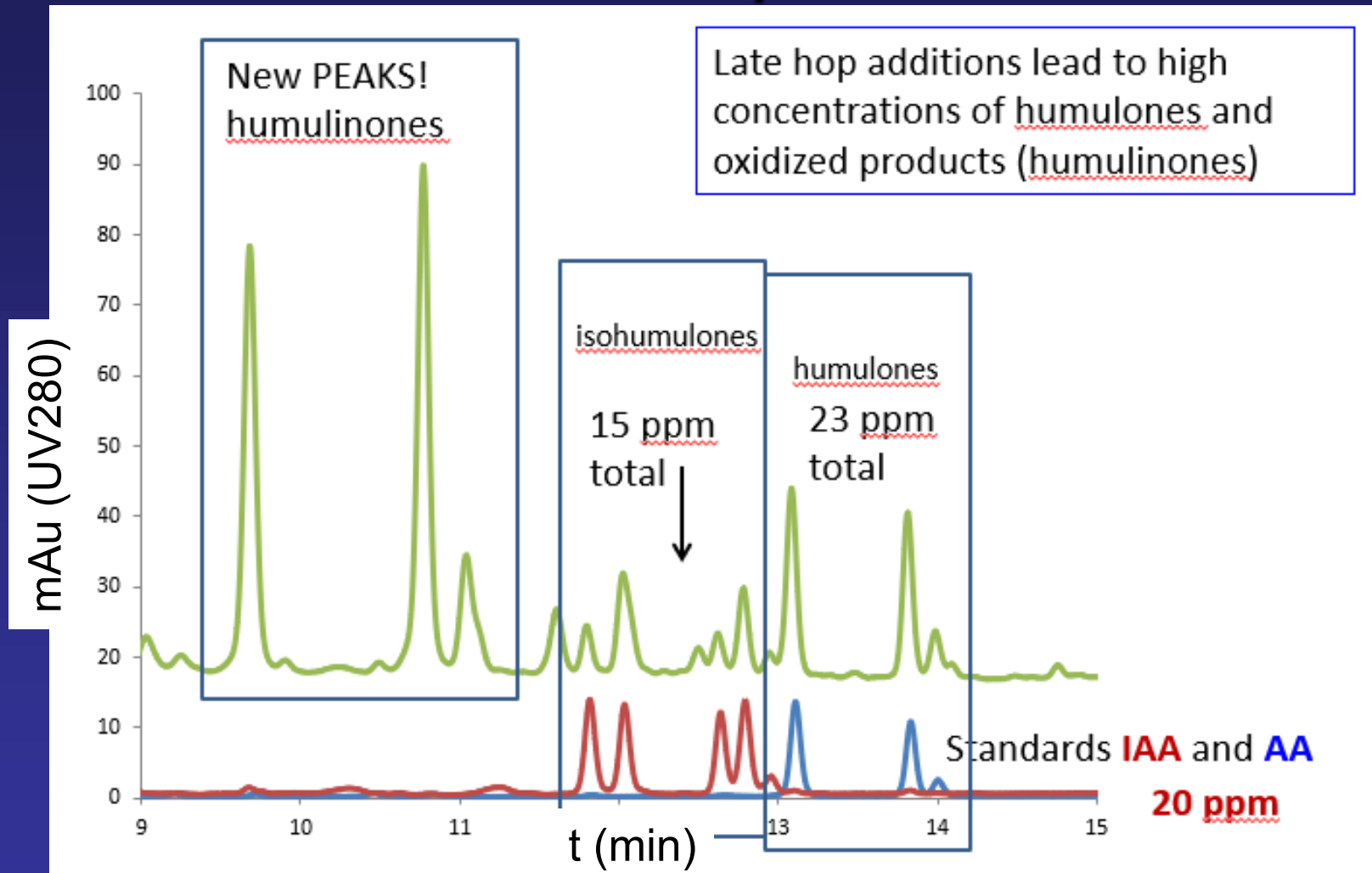
Reverse phase HPLC of extracted humulones and isomerized iso-humulones
C18 column; CH₃CN/H₂O/0.1% TFA; gradient elution

HPLC: Commercial Lager



Reverse phase HPLC; C18 column; CH₃CN/H₂O/0.1% TFA; gradient elution
UV detection 280 nm

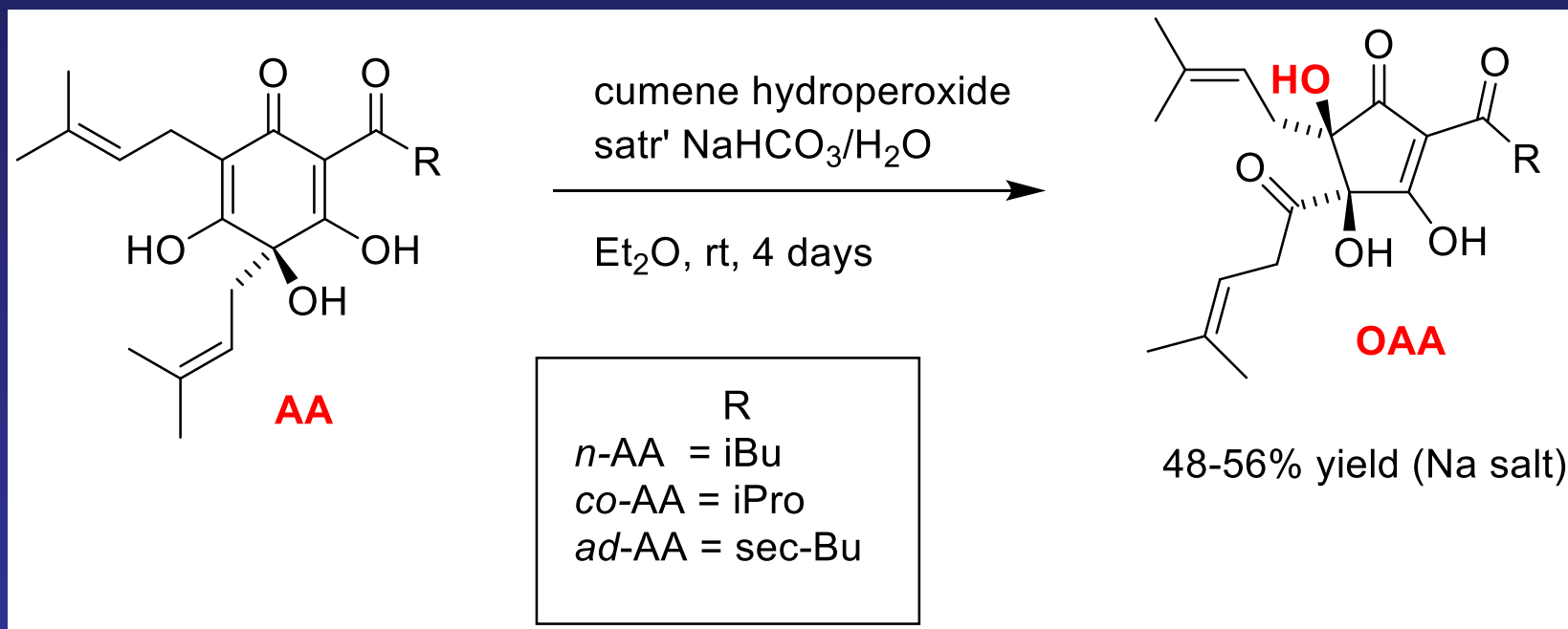
HPLC: Imperial IPA



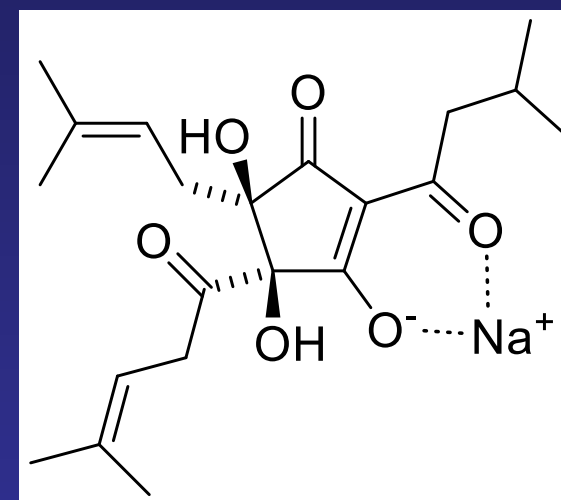
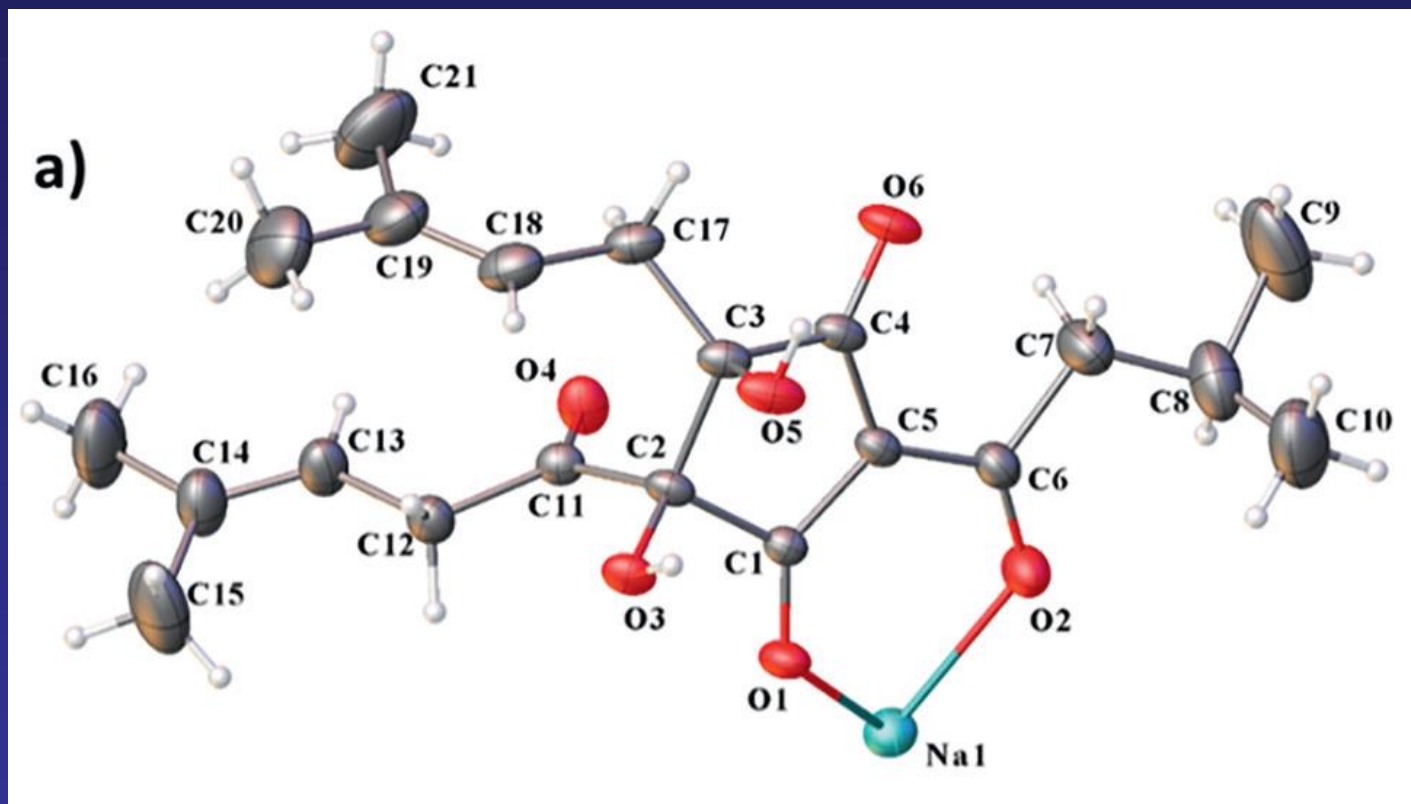
Reverse phase HPLC; C18 column; CH₃CN/H₂O/0.1% TFA; gradient elution
UV detection 280 nm

Synthesis of Humulinone Standards

cis-isohumulinones (OAA)



n-Humulinone Sodium Salt



cis isomer - racemate

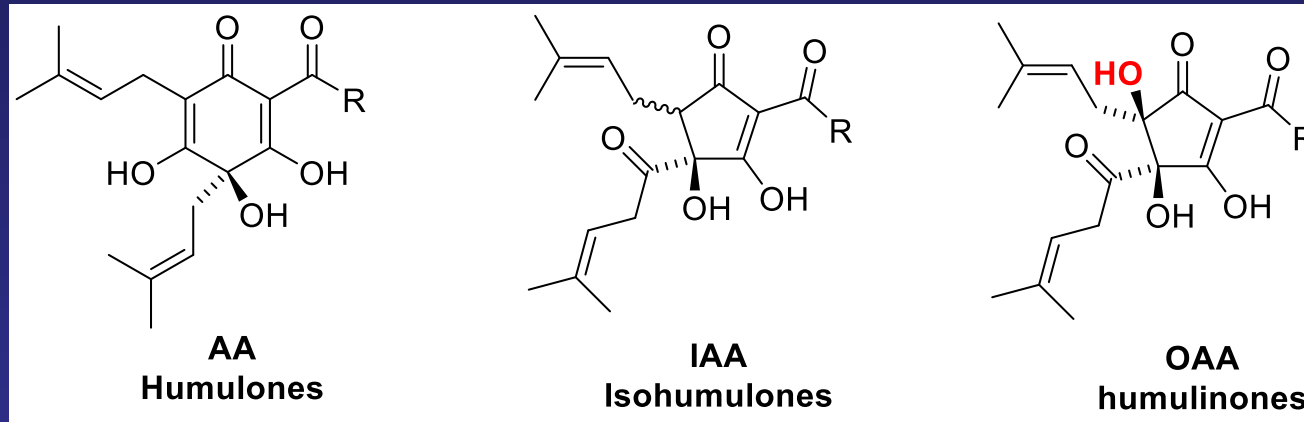
HPLC Results:

Humulones and Derivatives (AA, IAA, OAA)

Style	Name	IBU	<u>Oxidized humulone</u>	Isohumulone (IAA)	Humulone (AA)
American Porter	Naturalized Citizen	26	6.8	7.3	5.1
Pale Ale	UMSL Pale Ale	27	11.0	12.0	6.0
Imp IPA	Drummer's Brew	127	27.0	39.6	27.2
Blonde Ale	Blonde Ale	18	6.3	7.7	4.5
NA Lager	Bud	6.0	0.2	6.5	0.1
Stout	Cherry Stout	18.6	1.0	11.4	0.3

Beer Bitterness

More than Just Isohumulones!

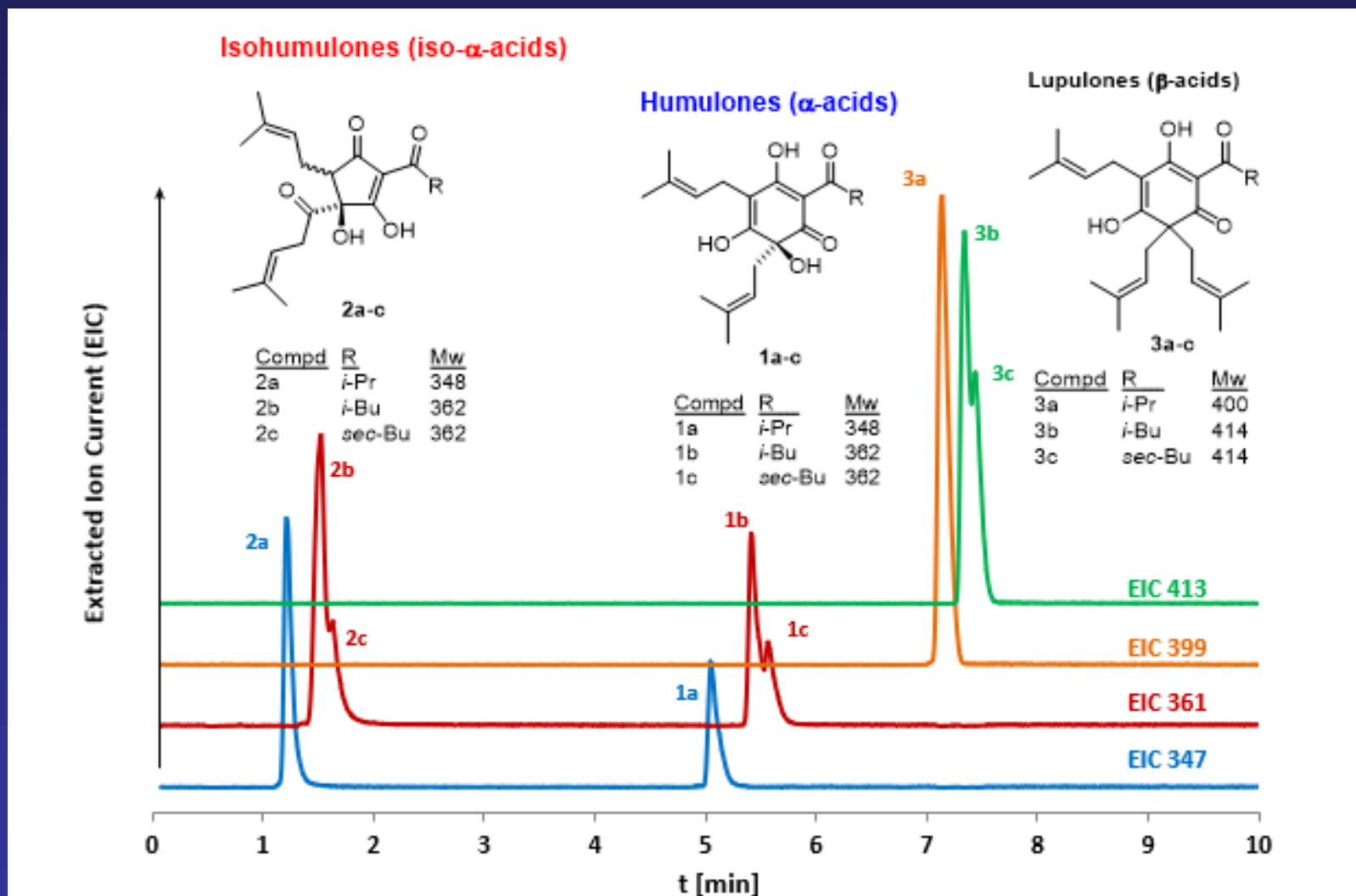


- Humulone, Isohumulone and Humulinone contribute to beer bitterness
- Beer Bitterness = $0.1 (\text{AA}) + 1.0 (\text{IAA}) + 0.66 (\text{OAA})^*$
- Additional additives can also contribute (Craft Beers)

J. P. Maye, J. Am. Soc. Brew. Chem. 74(1), 2016, 57-60.

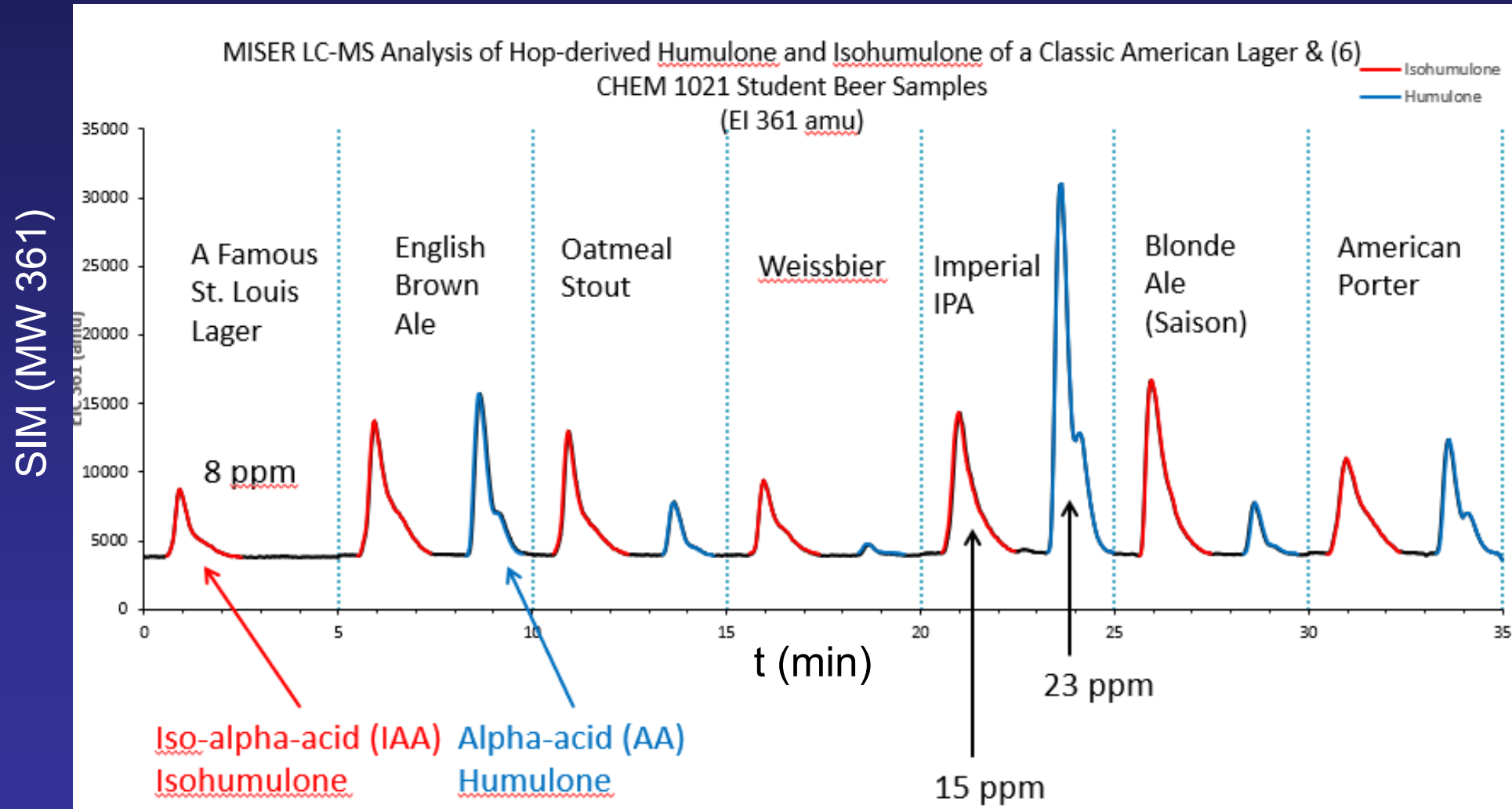
T. Shellhammer, J. Am. Soc. Brew. Chem. 74(1), 2016, 36-43.

LCMS – Analysis of Standards

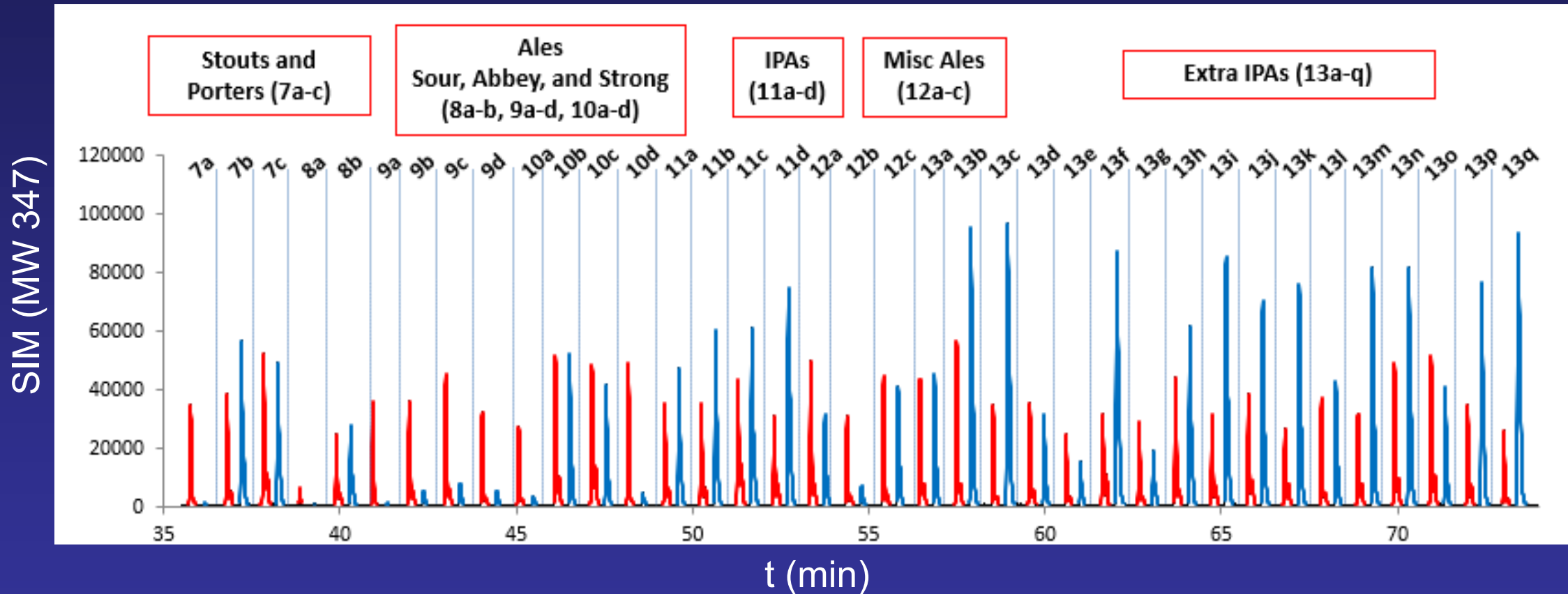


LCMS: Isohumulone/humulone Comparison

CHEM 1021 Beer Samples

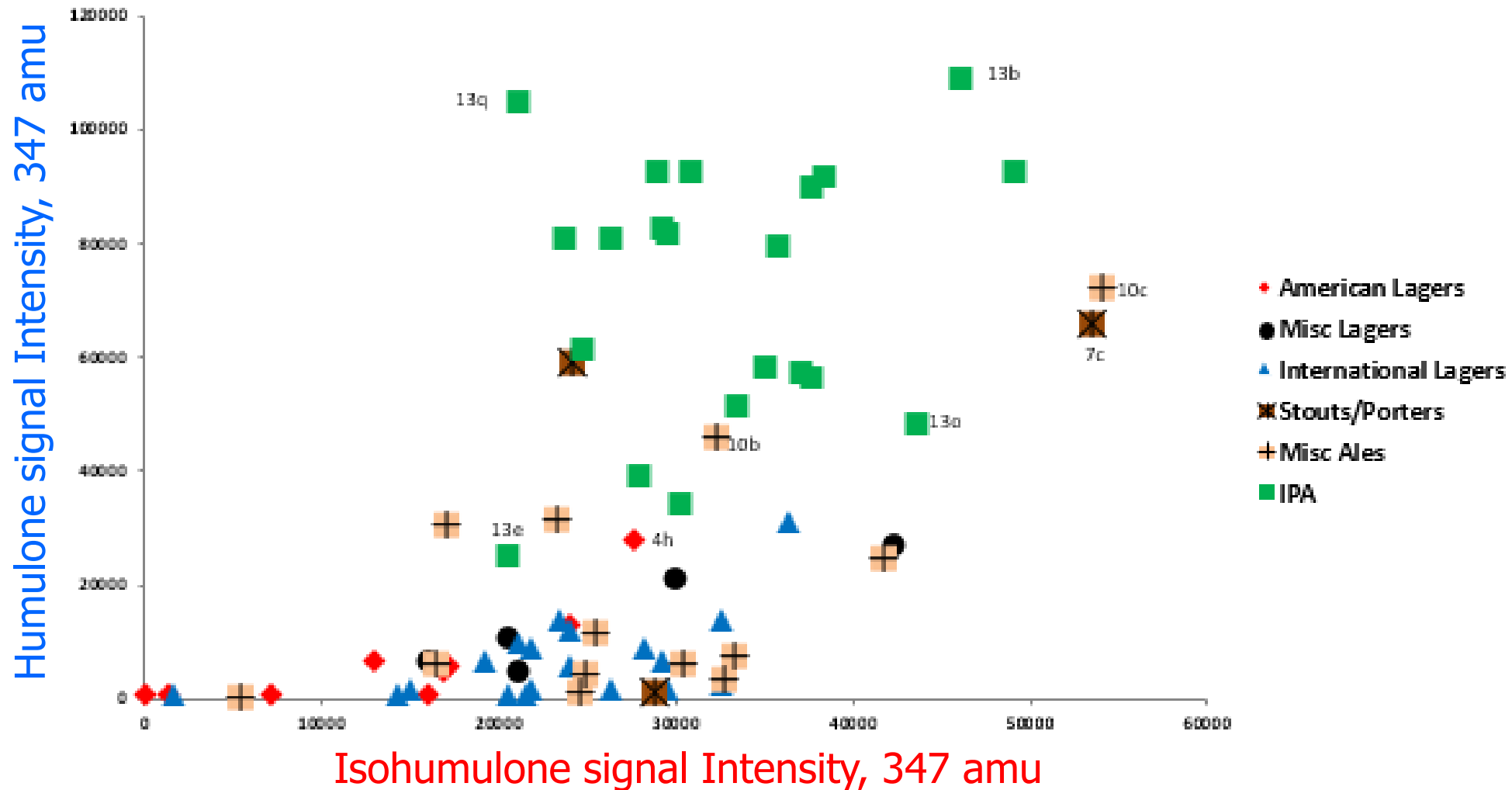


LCMS: Fast Analysis; 1 min/sample

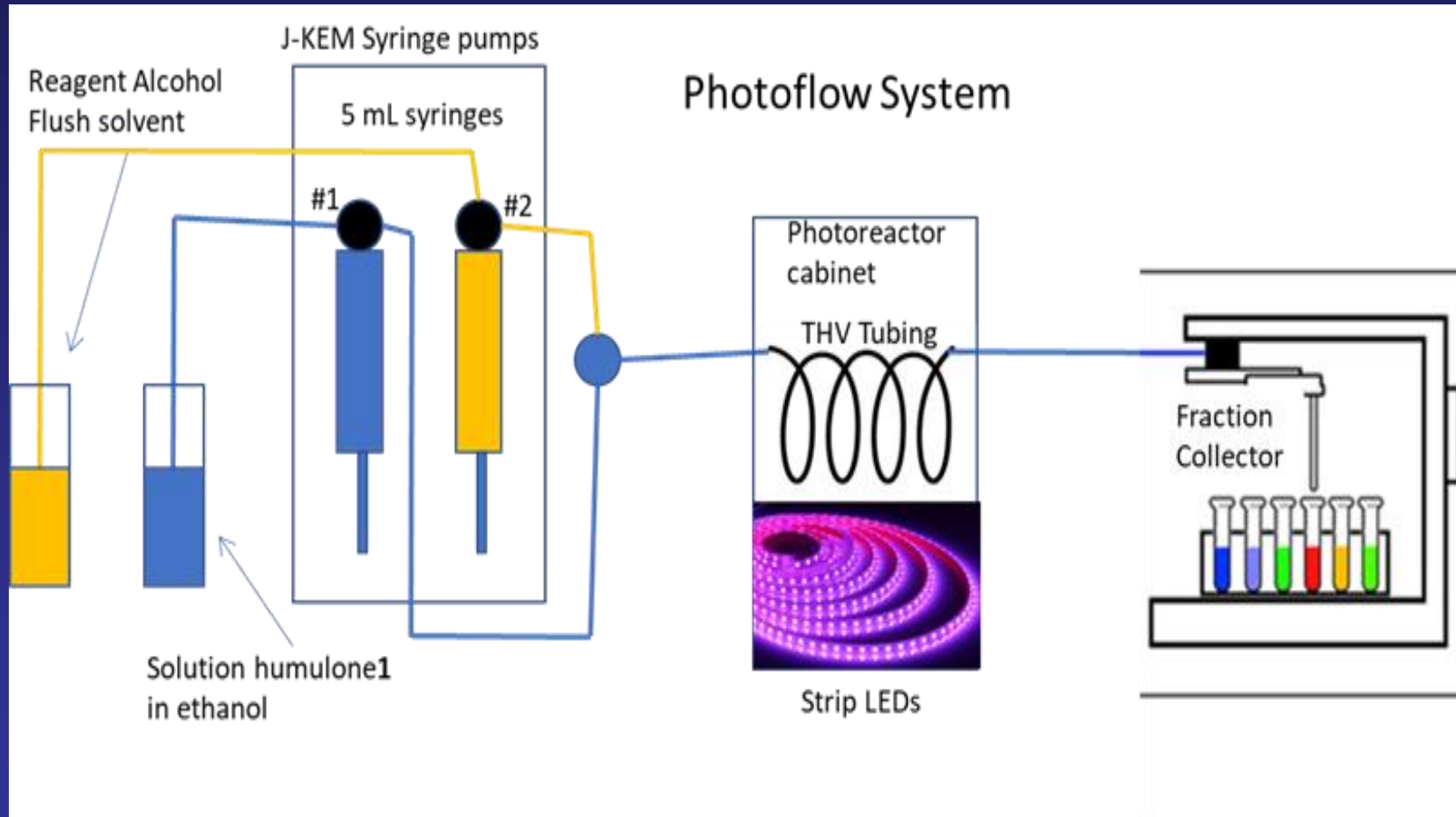


KEY: Blue peaks (AA, humulones); Red peaks (IAA, isohumulones)

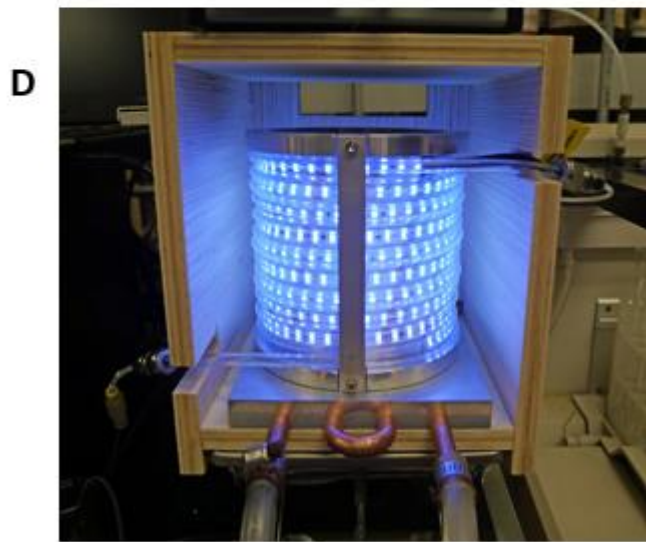
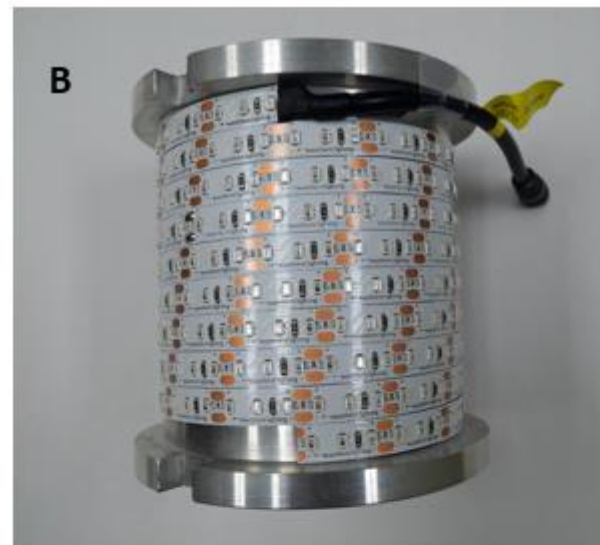
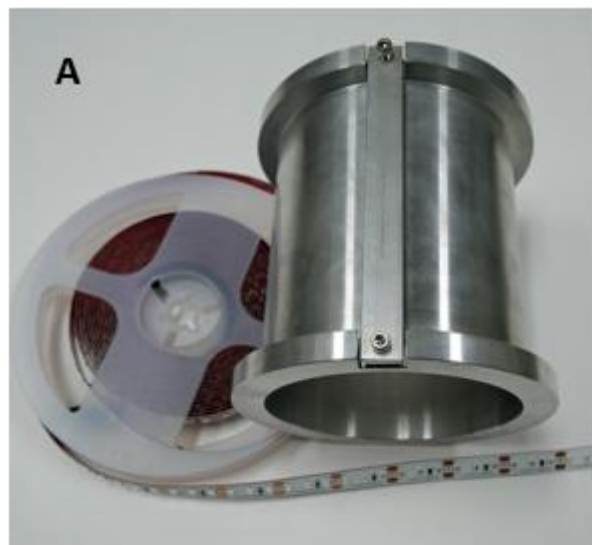
Comparison of Humulone and Isohumulone Content



Continuous Flow Photochemical System

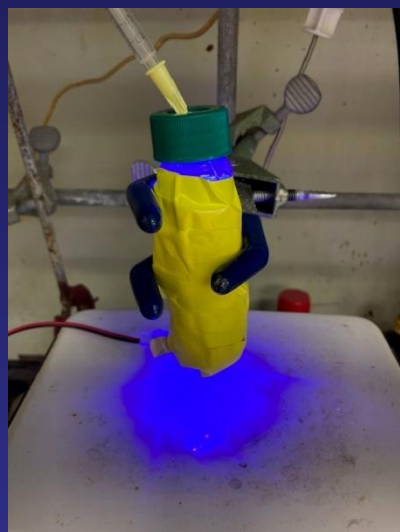


Photochemical Flow Reactor

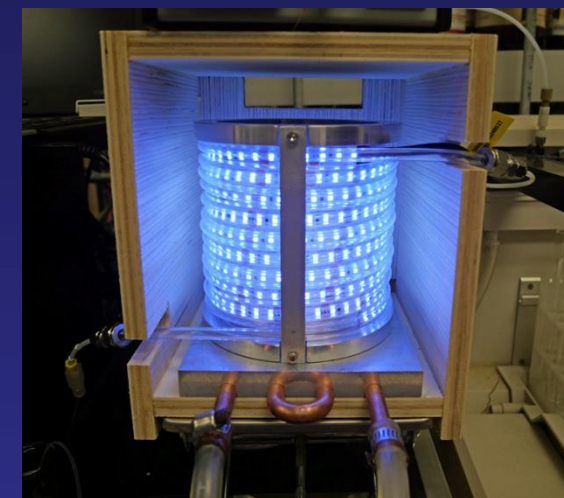
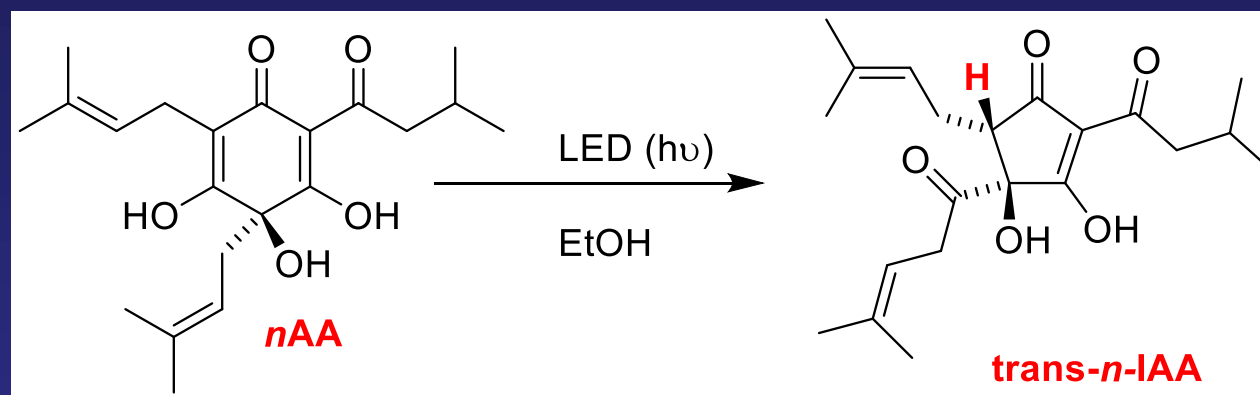




Photochemical Flow Synthesis



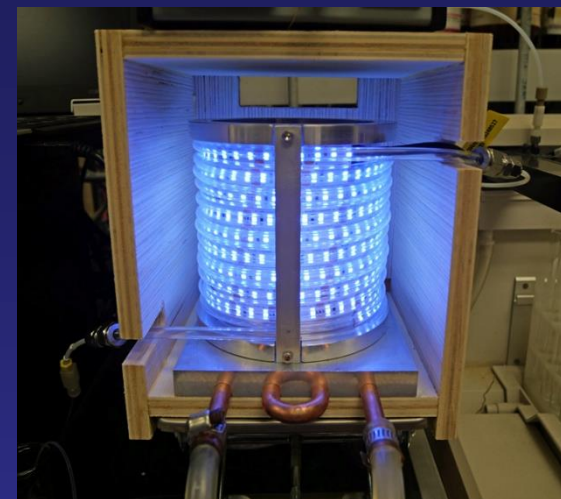
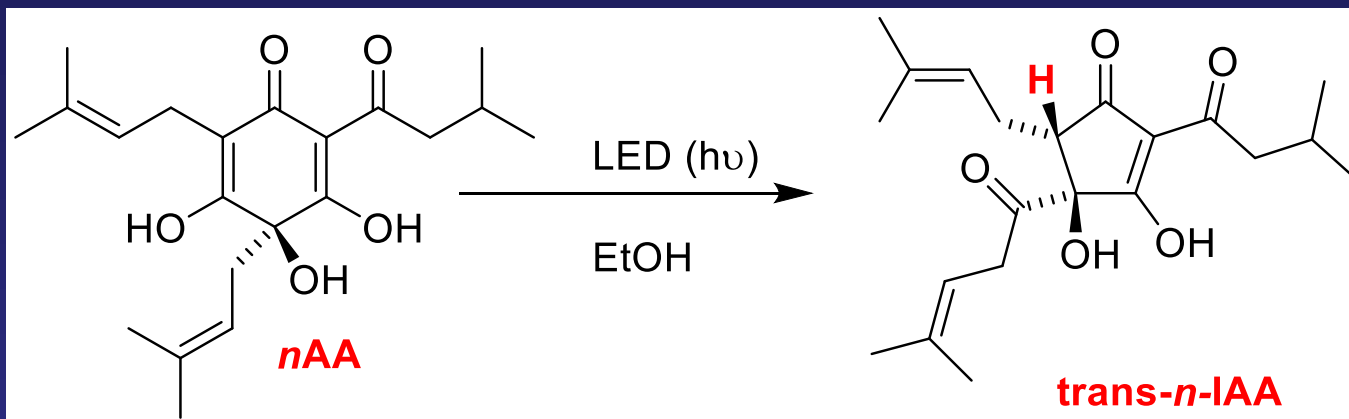
Photochemical
Batch Reactor



Photochemical
Flow Reactor

Reactor	Trans (%)	Yield (%)
Batch	>95	36%
Flow (white LED)	-	6%
Flow (365 nm)	79	95%
Flow (395 nm)	99	97%

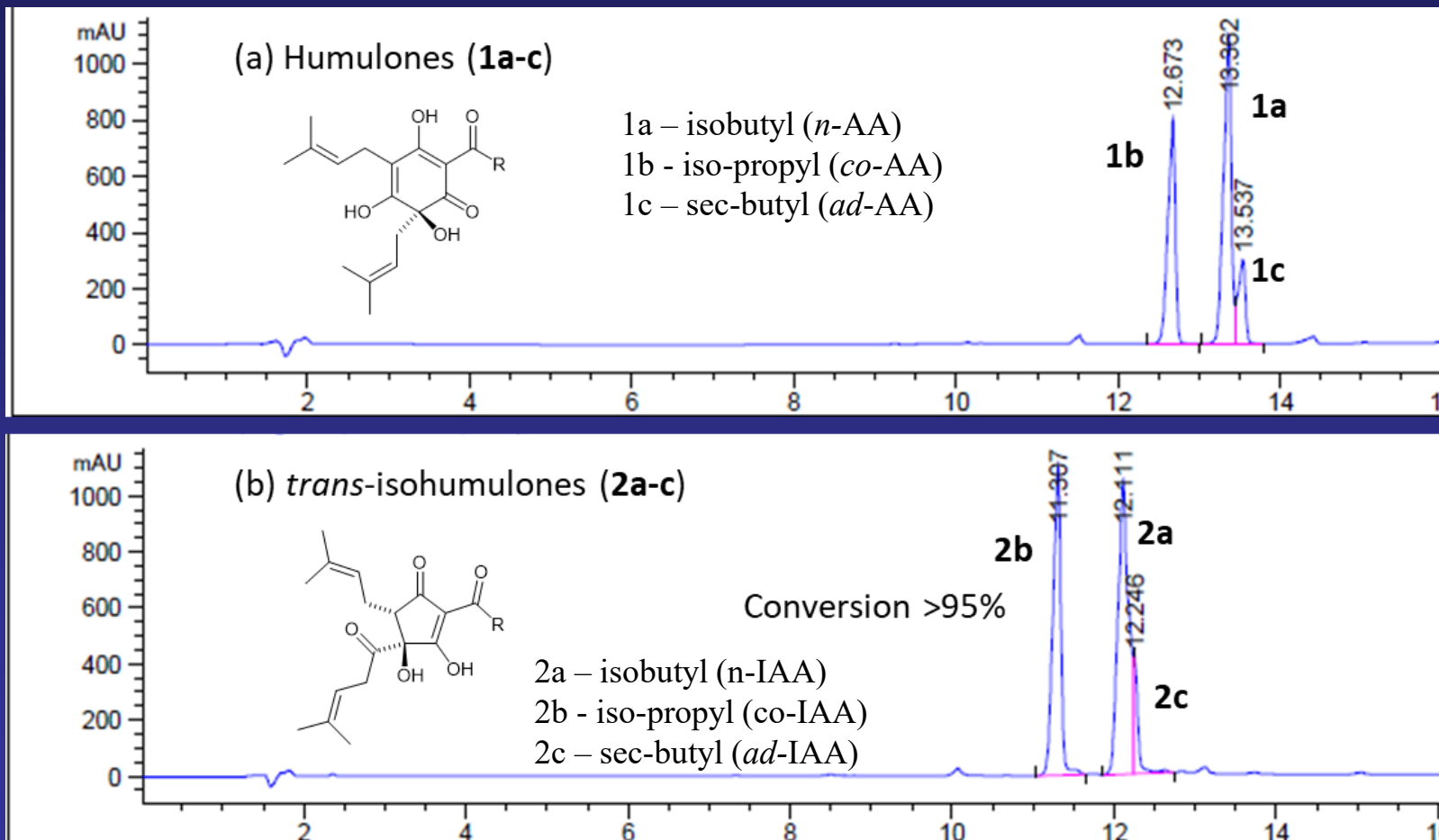
Photochemical Flow Throughput



Photochemical
Flow Reactor

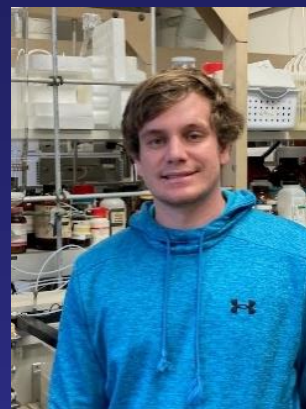
Photoreactor	Flow Rate (mL/min)	Conc (mM)	Throughput (g/h)
400 nm, 17 W	1.0	6.6	0.143
400 nm, 17 W	0.25	23	0.125
365 nm, 46 W	1.0	25	Mixture of isomers (80:20)
395 nm, 42 W	1.0	20	0.434

Photoflow Synthesis of Isohumulone Homologs



Reverse phase HPLC; C18 column; CH₃CN/H₂O/0.1% TFA; gradient elution
UV detection 280 nm

UMSL Flow Chemistry Team



Brewery Tour

Urban Chestnut Brewing Company



Acknowledgements

Dr. Eden Tesfu

Michael Mannino

Alex Lyss

Paul Meuser

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Liam Harrison

Brendan Sullivan

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Jason Triplett

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*Nick Viriyasiri

*Aaron Boland

Olivia Hermann

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*Matthew Murphy

***Dr. Joseph Meisel (GWU)**

Dr. Claire Brook

***Patrick Gleason**

*Kurt Driesner (UCBC)

***Dr. Chris Welch (Merck)**

*Kerstin Zawatzky

*Vivian Zhang

Dr. Stephen Kolodziej (Pfizer)

*Trevor Smith

*Tyler Kanady

*John Stamer

*Greg Giovine

*Bradley Gallow



* Beer Science/Flow Chemistry Team

