



# Analysis of Beer by Differential Mobility Spectrometry (DMS) Unexpectedly Revealed that Dynamic Ion Microsolvation can Promote Chemical Transformations

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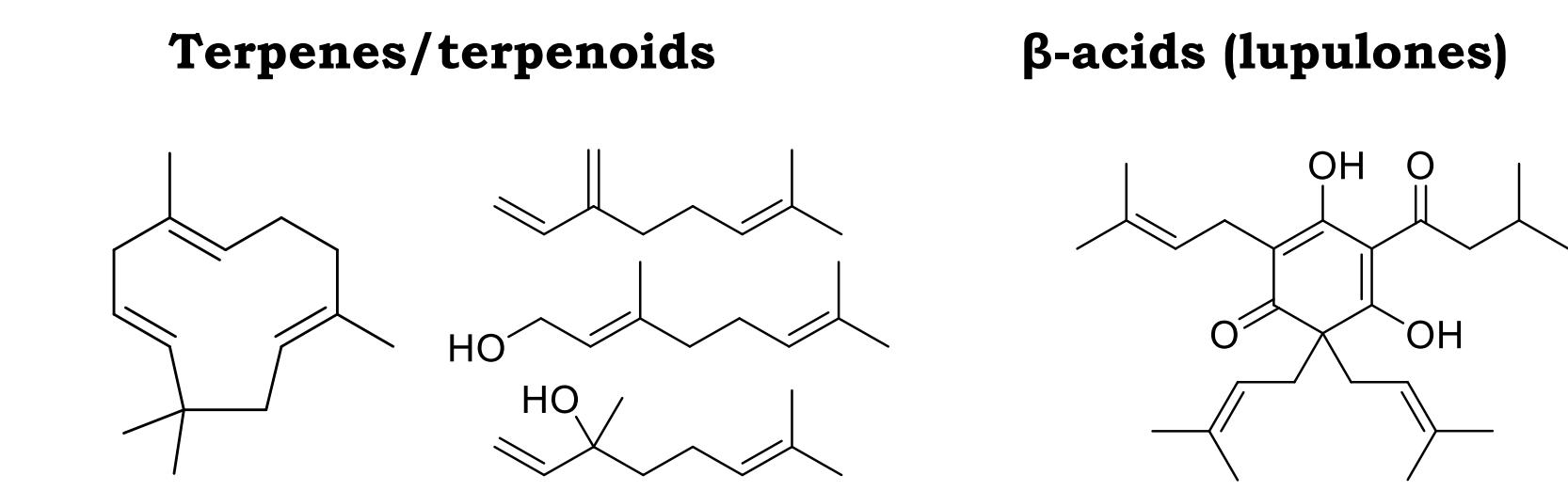
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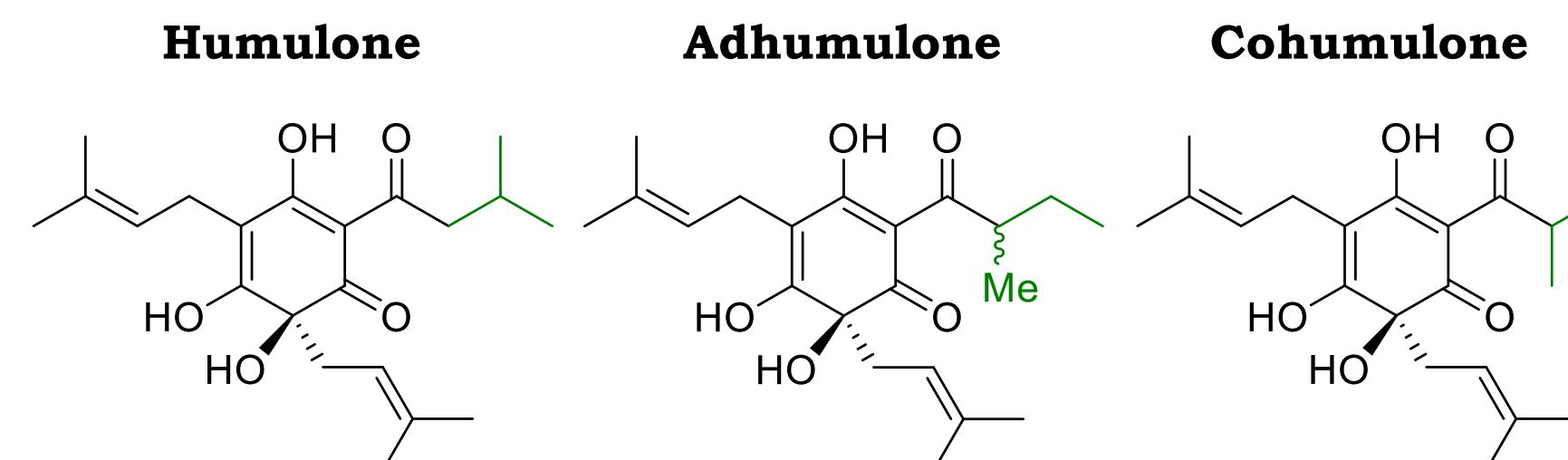
## Beer wouldn't be beer without humulone

Hops contain many natural products that are integral to a beer's composition. The terpenes/terpenoids contribute to the aroma of beer while preventing bacterial growth. The humulones ( $\alpha$ -acids) and isohumulones provide necessary bitter flavours to counteract sweetness. Quality control of commercial beers must separate and quantitate the (iso)- $\alpha$ -acids, which is done by LC over **20 to 40-minute runs**.<sup>1</sup> Can DMS do better? Who knows, no one has tried it yet!

### Aromas and antimicrobial/antibacterial activity

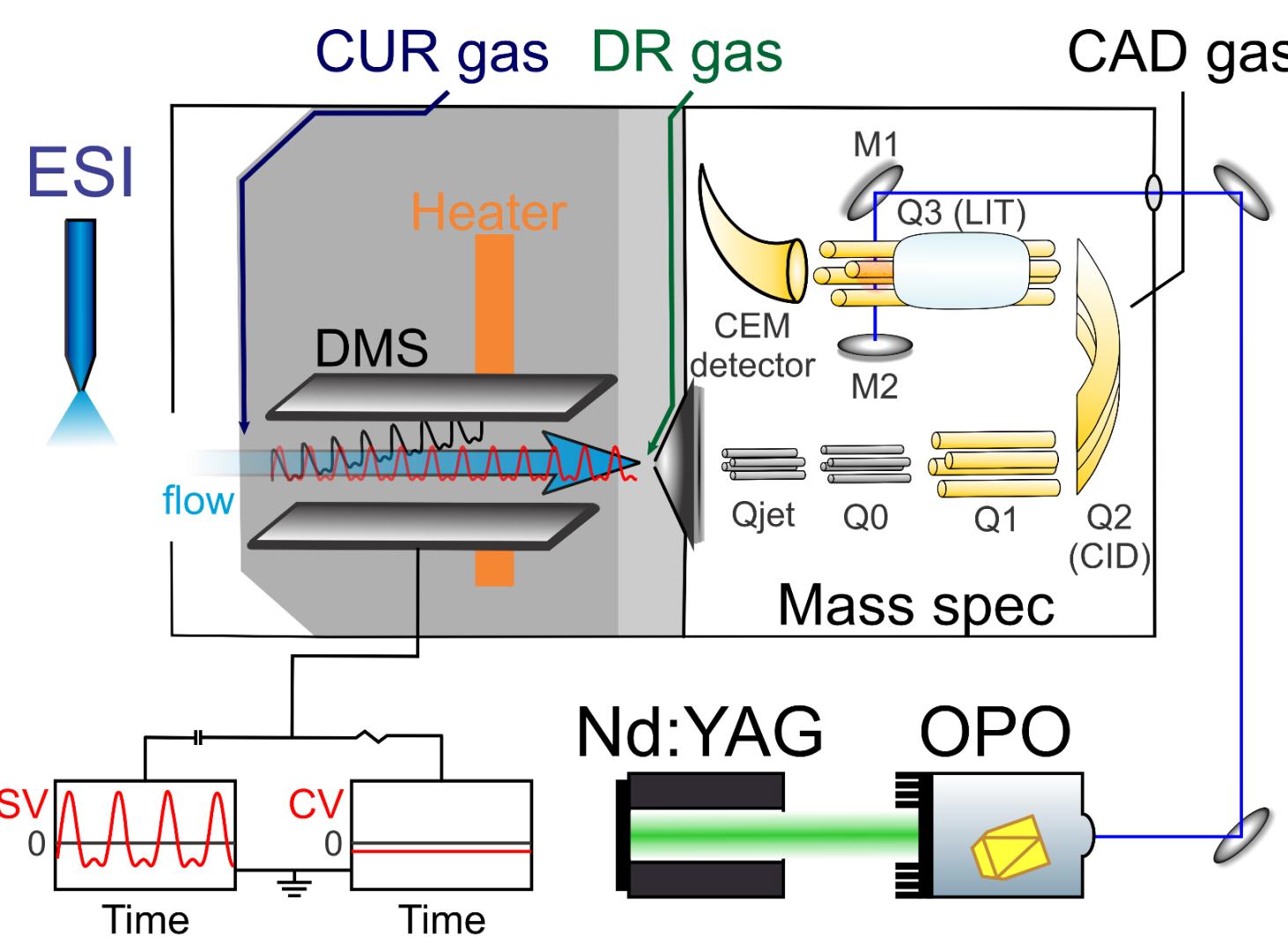


Bitter flavours to counter malt sweetness ( $\alpha$ -acids)



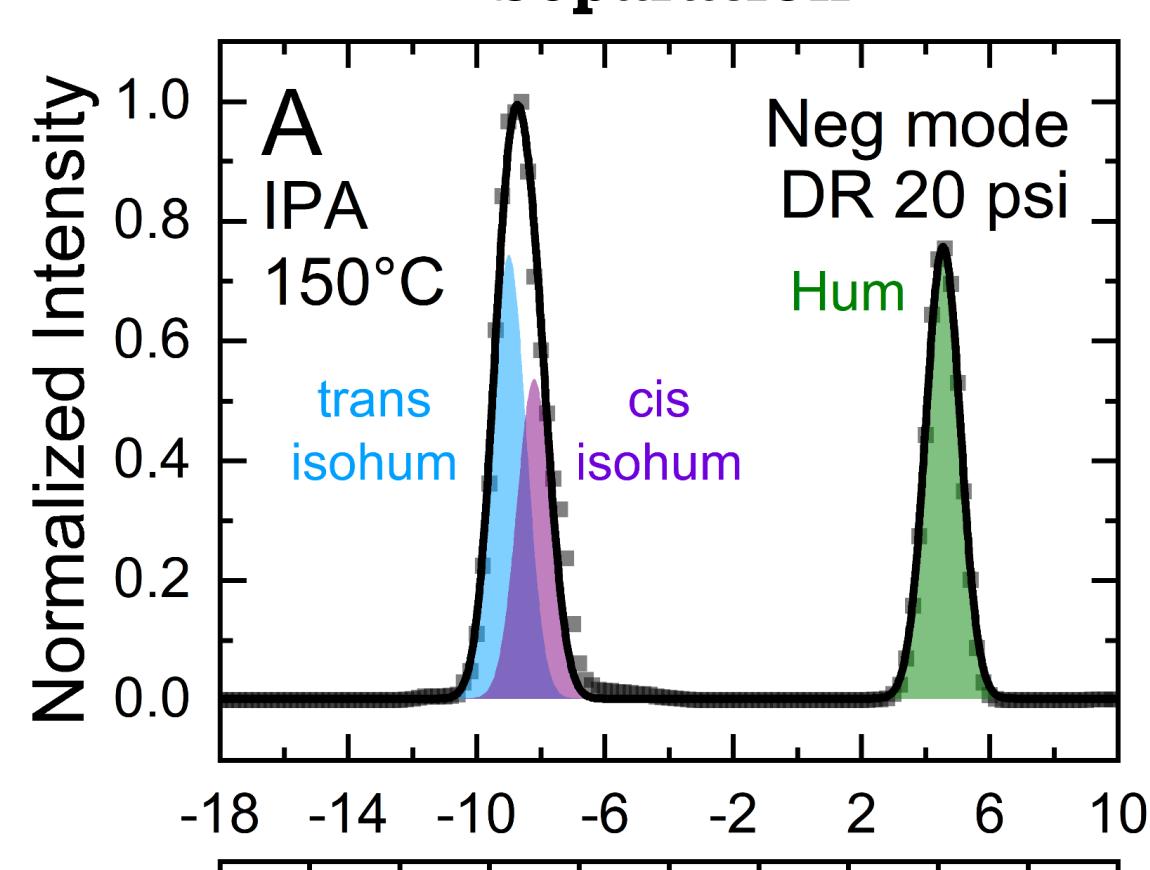
## Can DMS separate humulone better than LC?

Analytes are introduced to the DMS by electrospray ionization (ESI). Doping the DMS curtain gas with solvent vapour induces dynamic microsolvation cycles that enhance differences between the analyte's mobility during high and low-field portions of the SV, enabling separation in CV space. Analytes are detected by mass spectrometry (MS) and/or UV photodissociation (UPVD).

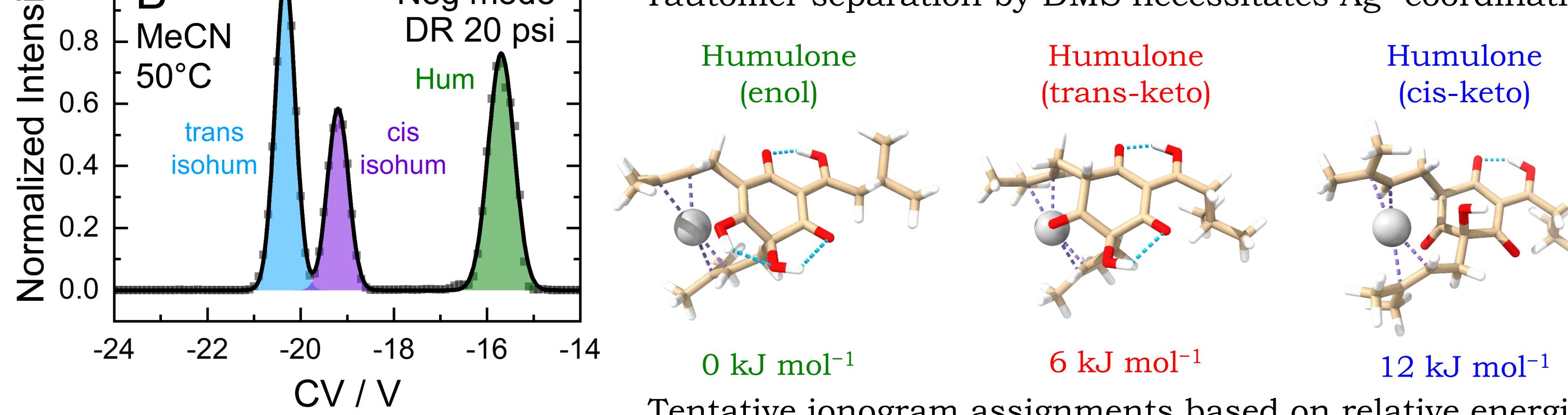


DMS separation of humulone from cis-isohumulone and trans-isohumulone is possible by monitoring  $[M - H]^-$  ions. But given that DMS can also resolve tautomers, can the enol, cis-keto, and trans-keto forms of humulone be resolved by DMS?

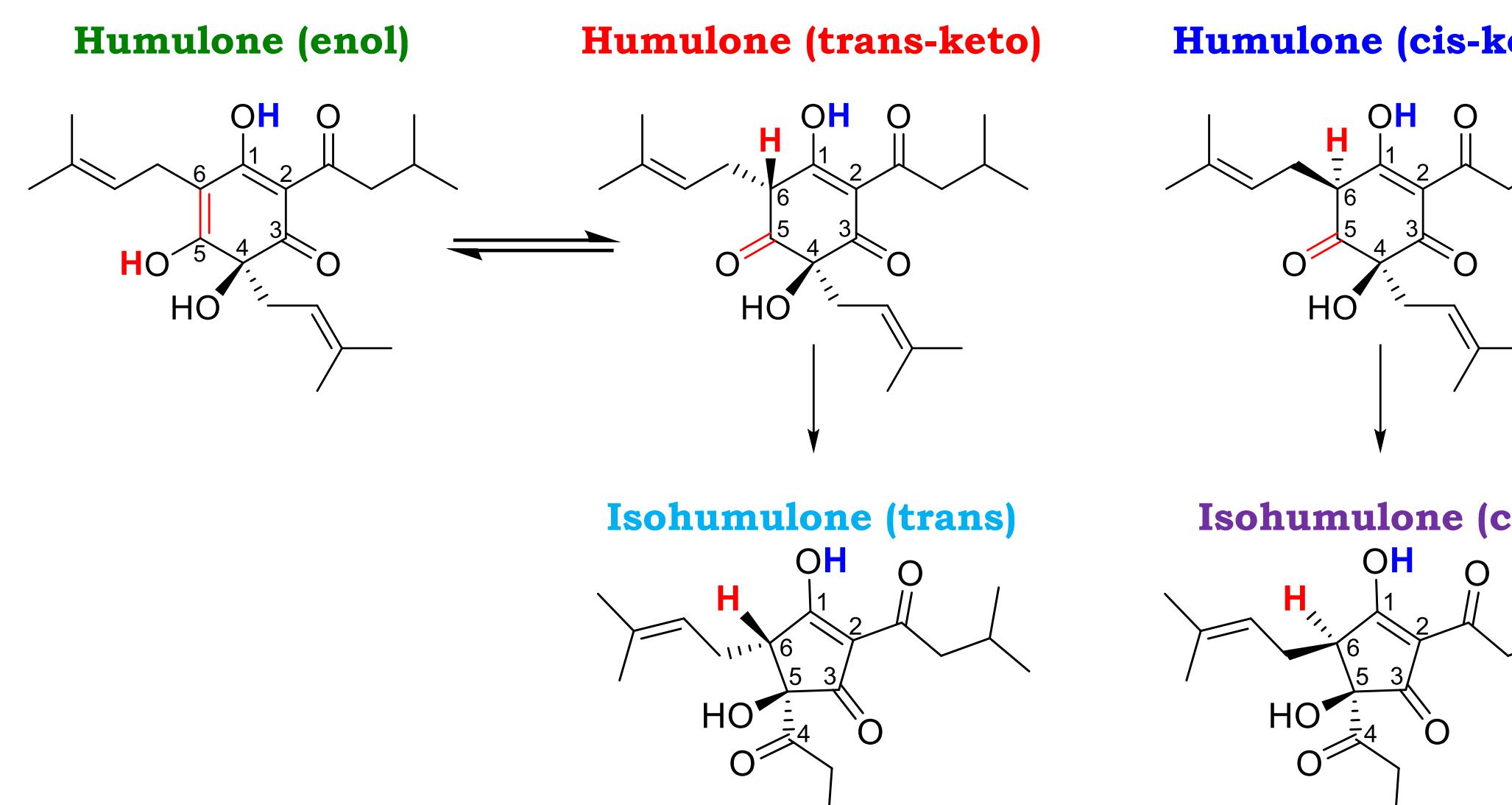
### Humulone/Isomulone Separation



### Enol/keto formation in the DMS requires + mode

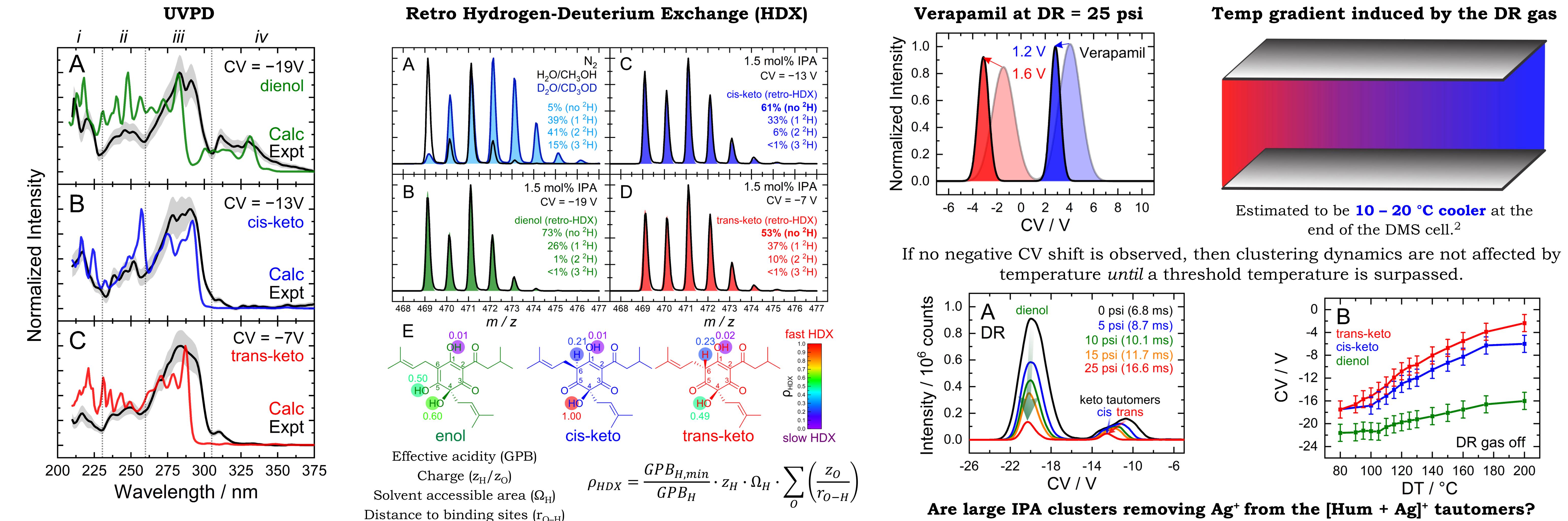


### Isomerization of the $\alpha$ -acids dictates a beer's IBU



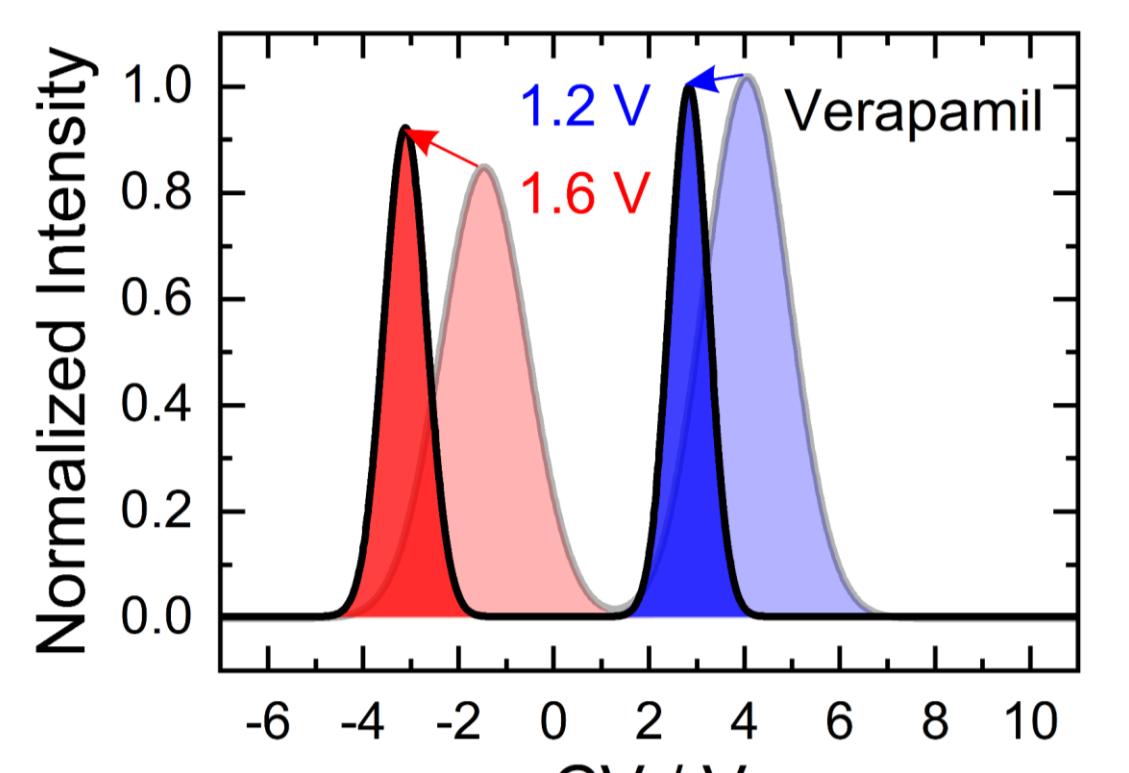
## Why does the DR gas induce coalescence of $[Hum + Ag]^+$ tautomers?

Understanding how the DR gas can hinder the resolution of  $[Hum + Ag]^+$  tautomers first requires us to confirm which peaks in the ionogram belong to the corresponding tautomer.

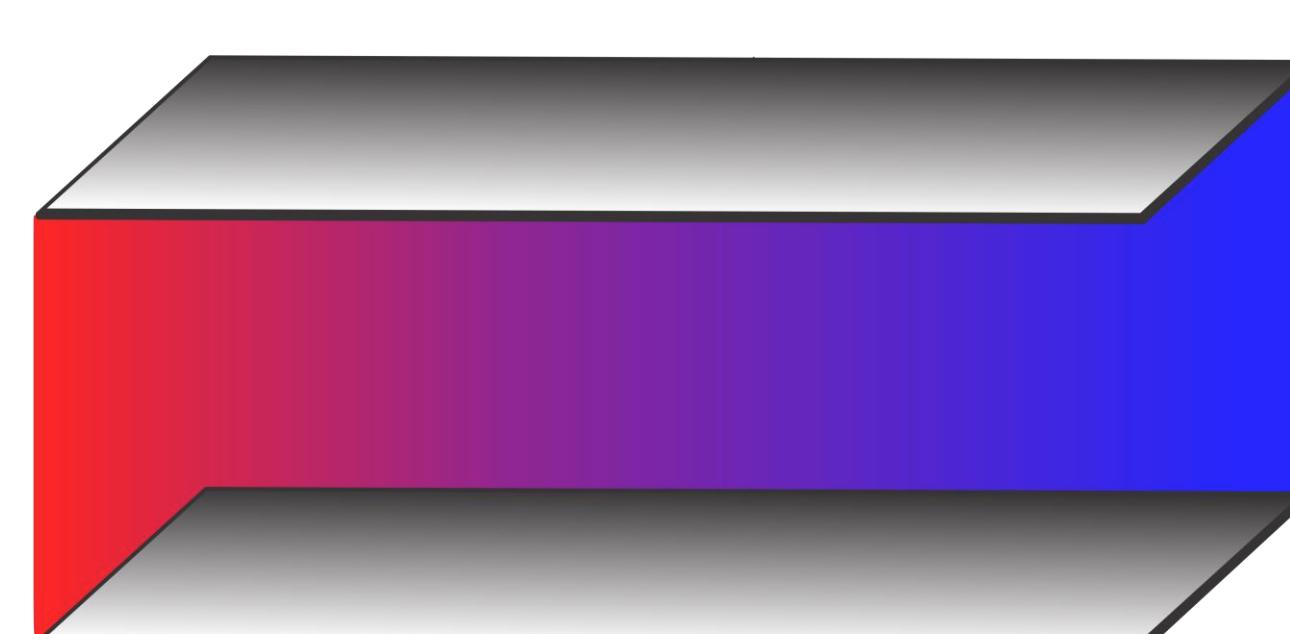


Usage of the DR gas normally results in negative CV shifts, which is caused by the introduction of a temperature gradient along the transmission axis of the DMS.

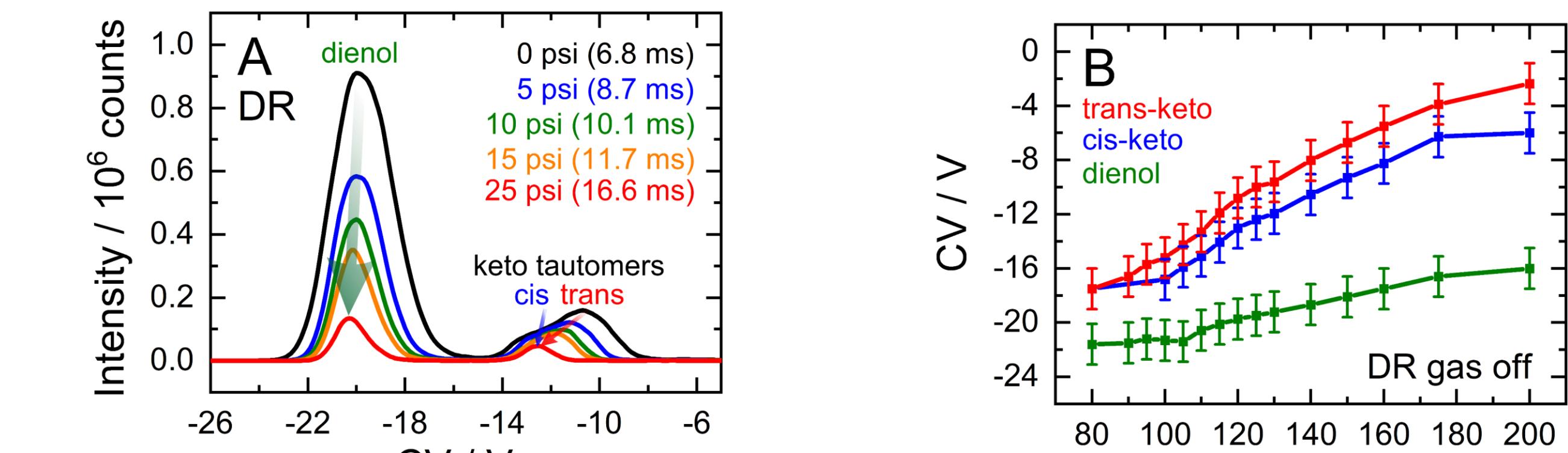
### Verapamil at DR = 25 psi



### Temp gradient induced by the DR gas

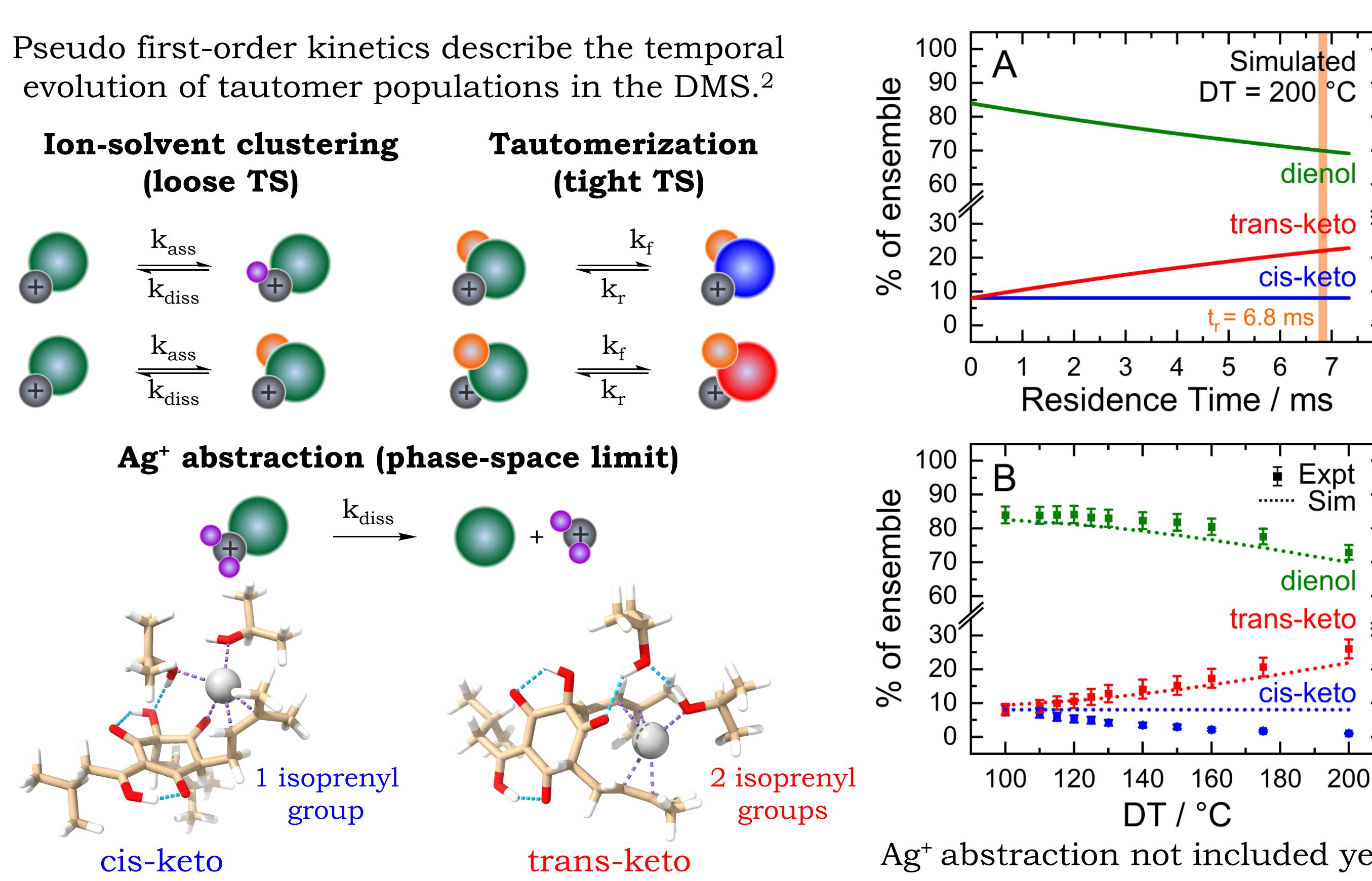


If no negative CV shift is observed, then clustering dynamics are not affected by temperature until a threshold temperature is surpassed.



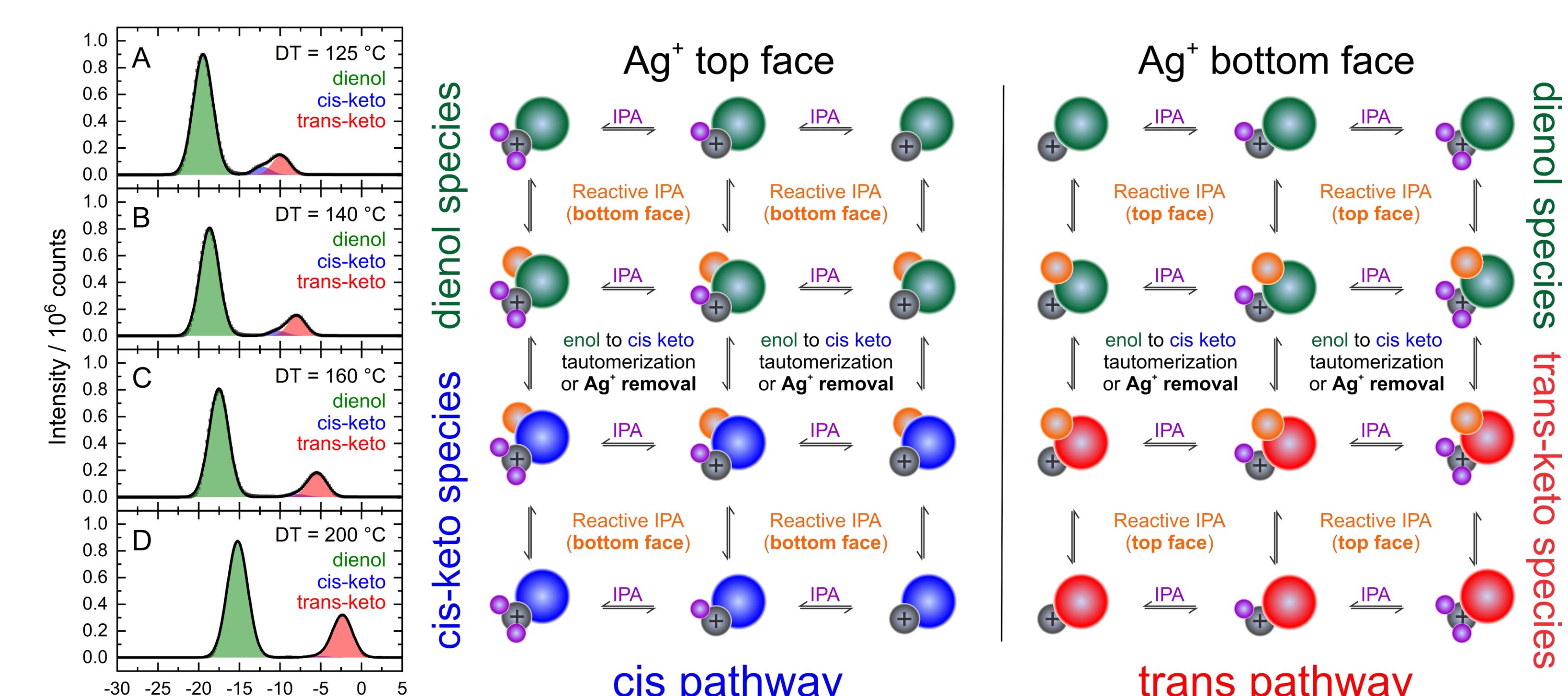
## Are large IPA clusters removing $Ag^+$ from the $[Hum + Ag]^+$ tautomers?

Simulating reaction kinetics within the DMS reveals that IPA mediates keto/enol tautomerization during the DMS separation.<sup>3</sup>



## Silver abstraction by IPA induces tautomerization of $[Hum + Ag]^+$ in the DMS!

Variations in DT ( $T_{\text{bath}}$ ) does not affect the enol peak intensity, but it does induce changes in the intensity of both keto features. There is more going than just silver abstraction!



## Concluding remarks

DMS can separate humulone from cis- and trans-isohumulone with ease. When humulone is coordinated to  $Ag^+$ , DMS can also separate the tautomeric forms of humulone. Curiously, when DMS resolving (DR) gas was applied to enhance tautomer separation, the cis- and trans-keto tautomers were no longer resolved. Understanding this behaviour required confirmation of tautomer assignments, which was afforded through UVPD and retro-HDX experiments. The loss in resolution was attributed to an IPA-mediated charge neutralization, whereby the enhanced temperature gradient introduced with the DR gas induced abstraction of  $Ag^+$  from  $[Hum + Ag]^+$ . Moreover, kinetic simulations indicate that IPA also facilitated tautomerization between the trans-keto and dienol forms of  $[Hum + Ag]^+$  as the complex traverses the DMS cell, which has yet to be observed on any ion mobility platform.

## References and acknowledgements

- J. Agric. Food. Chem. 2009, 57, 4, 1172 – 1182.
- Mass Spec. Rev. 2016, 35, 6, 687 – 737.
- J. Am. Soc. Mass Spectrom. 2022. Published.



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