Reliable EACN Determination for Dead and Live Crudes in Microemulsion Systems

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Background

Successful surfactant flooding maximizes oil recovery by achieving ultralow IFTs at the optimal salinity (S*), which is dependent on the equivalent alkane carbon number (EACN) of the oil pseudocomponent. Recent literature suggests that the EACN of oil mixtures does not follow the linear mixing rule.

$$EACN = \sum_i x_i EACN_i$$

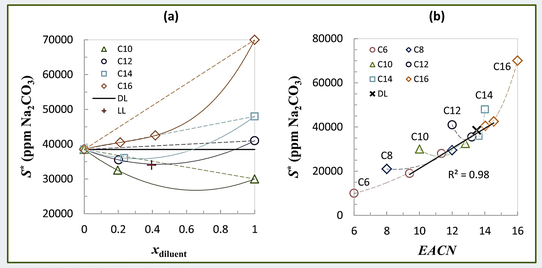

Fig. 1 - Does EACN follow a non-linear mixing rule? Data from Jang and Pope 2023.

"The simplest explanation is usually the best one"
-Occam's Razor Philosophy

Objectives

- Find an unbiased method to determine the optimal formulation conditions.
- Show that the linear mixing rule applies.
- Find the optimum surface with key formulation variables.

Microemulsion Phase Behavior

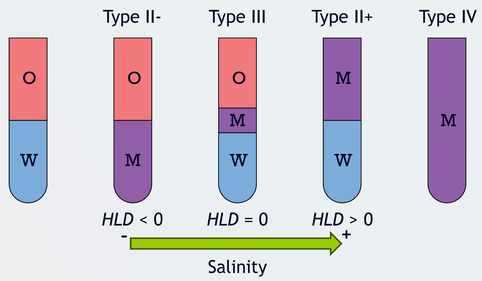

Fig. 2 - Illustration of microemulsion phase behavior types.

From HLD-NAC Equation of State (for Type III):

Planar

$$\frac{1}{\sigma_i} = m_{S,i} \ln S + m_{EACN,i} EACN + m_{P,i} P + m_{T,i} T$$

Straight Line (Const. T, P, EACN)

$$\frac{1}{\sigma_i} = m_i \ln S + b_i$$

S = Salinity
T = Temperature
P = Pressure
EACN = Equivalent Alkane Carbon Number

$\sigma_i = \frac{V_{iM}}{V_{surf}}$ = solubility ratio

Unbiased Graphical Approach to Determine Optimum Salinity

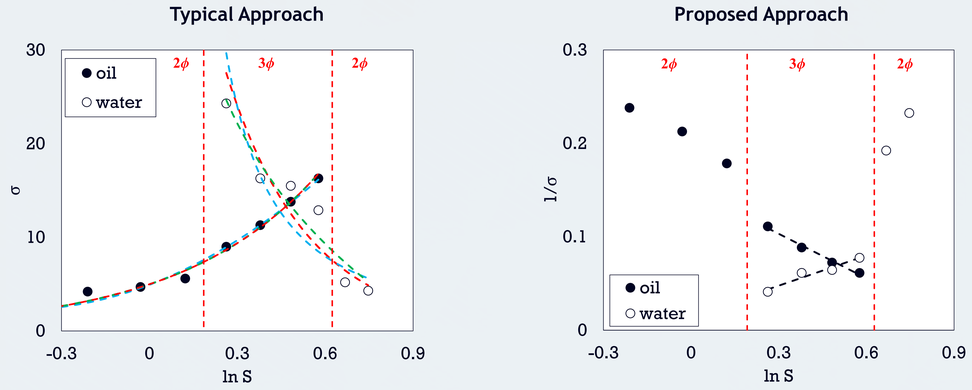

Fig. 3 - Comparison of the typical approach and the proposed unbiased approach to determine the optimum from salinity scan data. Data after Roshanfekr and Johns 2011.

EACN Determination Methods

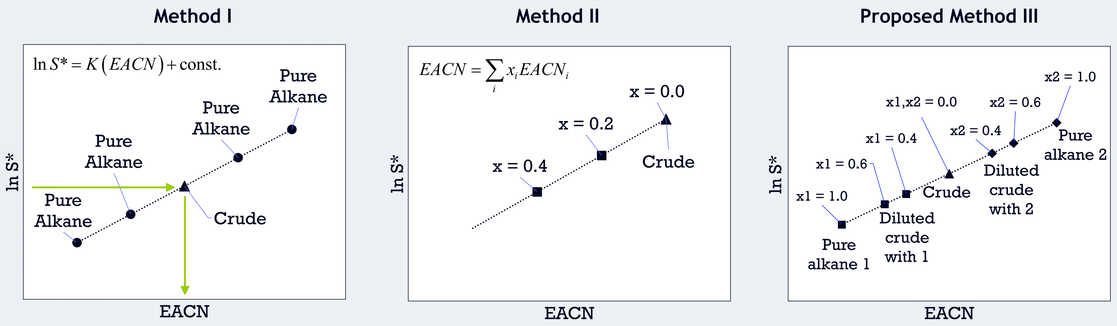

Fig. 4 - Illustration of Methods I, II, and III (proposed) to determine the EACN of crude with unknown compositions. Method III is a combination of Methods I and II.

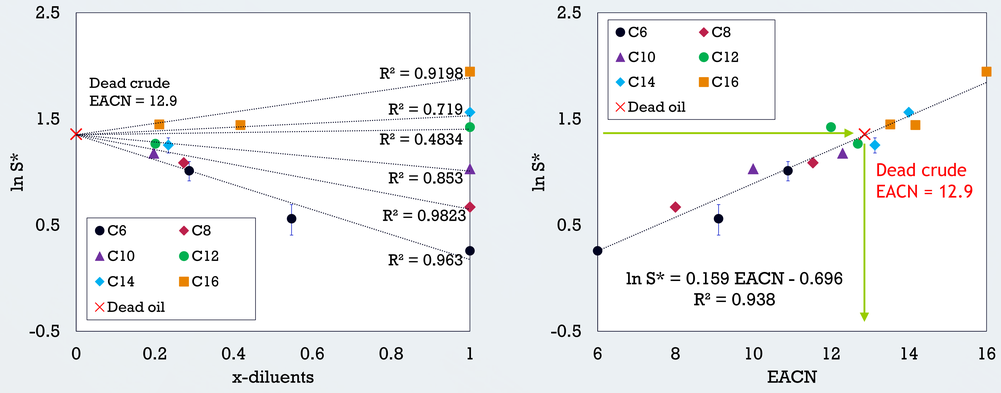

Fig. 5 - Demonstration of the proposed Method III to determine the EACN of dead crude with unknown compositions. R^2 decreases when crude is diluted with oil of similar EACN. Data after Jang and Pope 2023.

EACN Determination of Live Crude at Elevated Pressure

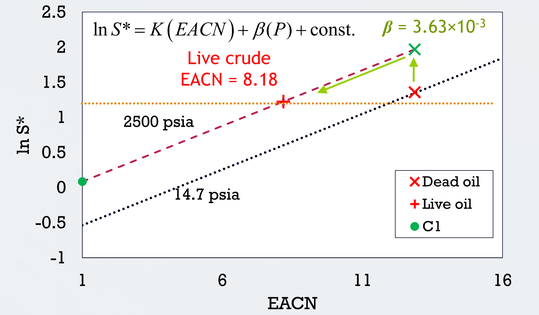

Fig. 6 - EACN determination of a live crude (dead crude + methane) at elevated pressure. Data after Jang and Pope 2023.

Optimum Line of the Formulation Conditions

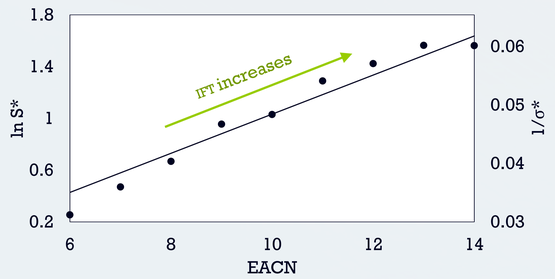

Fig. 7 - The optimum line of the formulation variables can be easily determined using the HLD-NAC concept.

Conclusions

1. Optimal salinity and solubility can be graphically estimated through unbiased linear regression in the three-phase region ($1/\sigma$ vs. $\ln S$).
2. Methods I, II, and III result in consistent EACN estimates when the graphical approach is used to determine the optimal salinity.
3. Pressure correction (β) should be measured and accounted for in the determination of live crude EACN.
4. The optimal plane in $\ln S$, EACN, T, and P can be determined from regression of all solubility data.

References

Jang, S.H., and Pope, G.A. 2023. Microemulsion Phase Behavior of Live Crude Oil and Revisiting the EACN Framework for Crude Oils. *Colloids and Surfaces A: Physicochemical and Engineering Aspects* 670 (August). https://doi.org/10.1016/j.colsurfa.2023.131565.

Roshanfekr, M., and Johns, R.T. 2011. Prediction of Optimum Salinity and Solubilization Ratio for Microemulsion Phase Behavior with Live Crude at Reservoir Pressure. *Fluid Phase Equilibria* 304 (1-2): 52-60. https://doi.org/10.1016/j.fluid.2011.02.004.

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