

Enhancing Low-Temperature Thermal Energy Storage with Next-Generation PCMs

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02 Problem

03 Experimental Methodology

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05 Acknowledgements

OVERVIEW

1

Phase Change Materials (PCM) for low-temperature Thermal Energy Storage (TES)

3

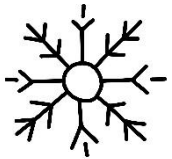
Study of binary mixtures of *n*-alkanes and *n*-alkyl adipates as potential PCMs

2

Phase Equilibrium Studies to determine temperature and enthalpy of fusion and understand phase change properties



PROBLEM



The focus of this work was low temperatures (between $-80\text{ }^{\circ}\text{C}$ and $-20\text{ }^{\circ}\text{C}$) for applications in the medical sector and cold chain logistics.



The available experimental techniques are very limited for low temperatures

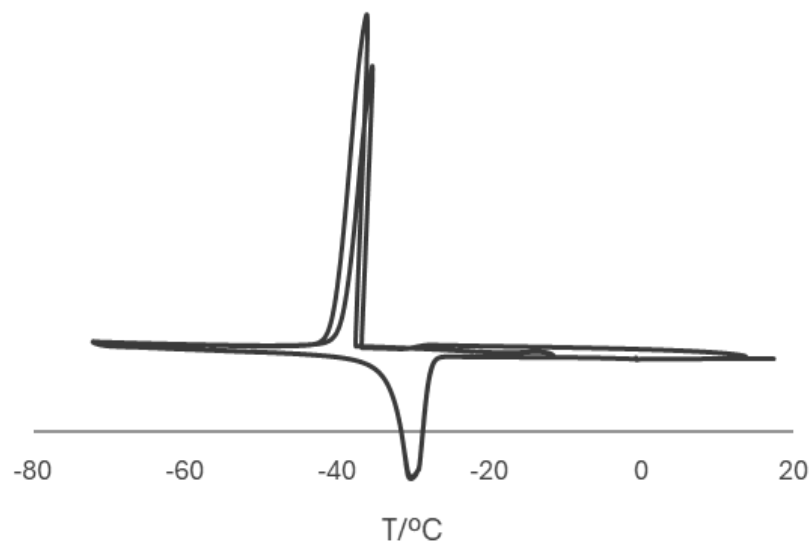


EXPERIMENTAL METHODOLOGY

- 1** Differential Scanning Calorimetry (DSC)
- 2** Hot-Stage Polarized Microscopy
- 3** Raman Spectroscopy

Differential Scanning Calorimetry (DSC)

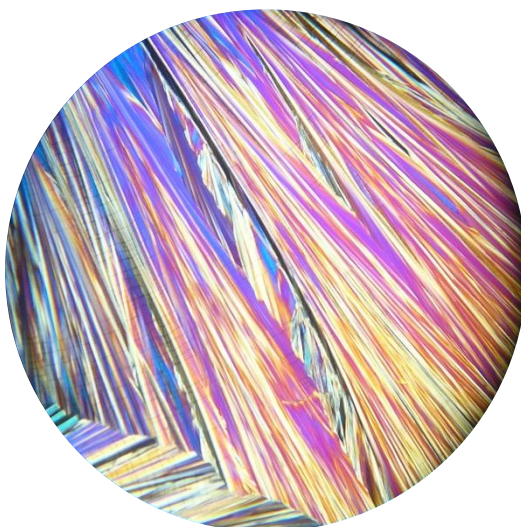
Thermal Analysis



Temperature and enthalpy of phase transition

Hot Stage Polarized Microscopy (HSPM)

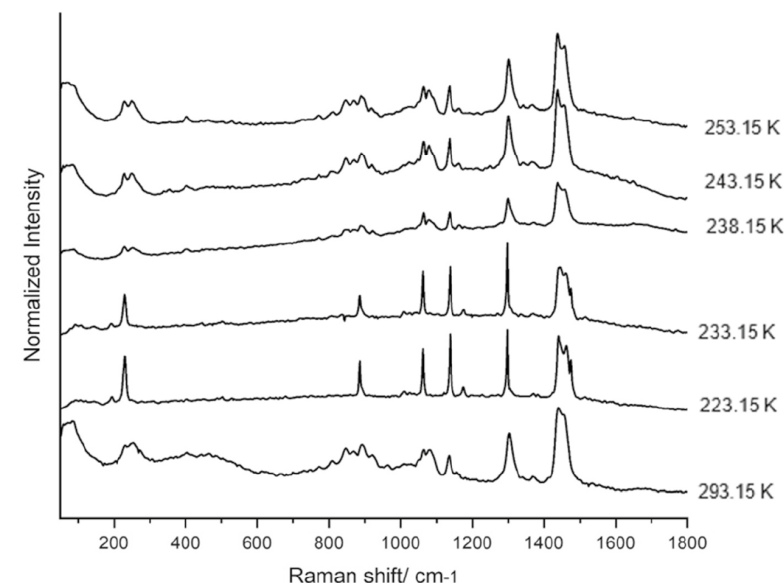
Microscopic Analysis



Real-time visual evidence of thermal events

Raman Spectroscopy

Spectroscopic Analysis



Identification and characterization of the thermal events

EXPERIMENTAL RESULTS

01 *n* - Alkanes

- Different phase equilibrium features: eutectic, congruent melting, peritectics
- Odd-even effects in phase equilibrium characteristics
- Polymorphism in odd pure compounds and some binary compositions

02 *n* -Alkyl Adipates

- Same phase equilibrium features: non-isomorphous eutectics
- Polymorphism in some pure compounds and some binary compositions

DSC THERMOGRAMS:

Partially isomorphous eutectic (C8+C10)

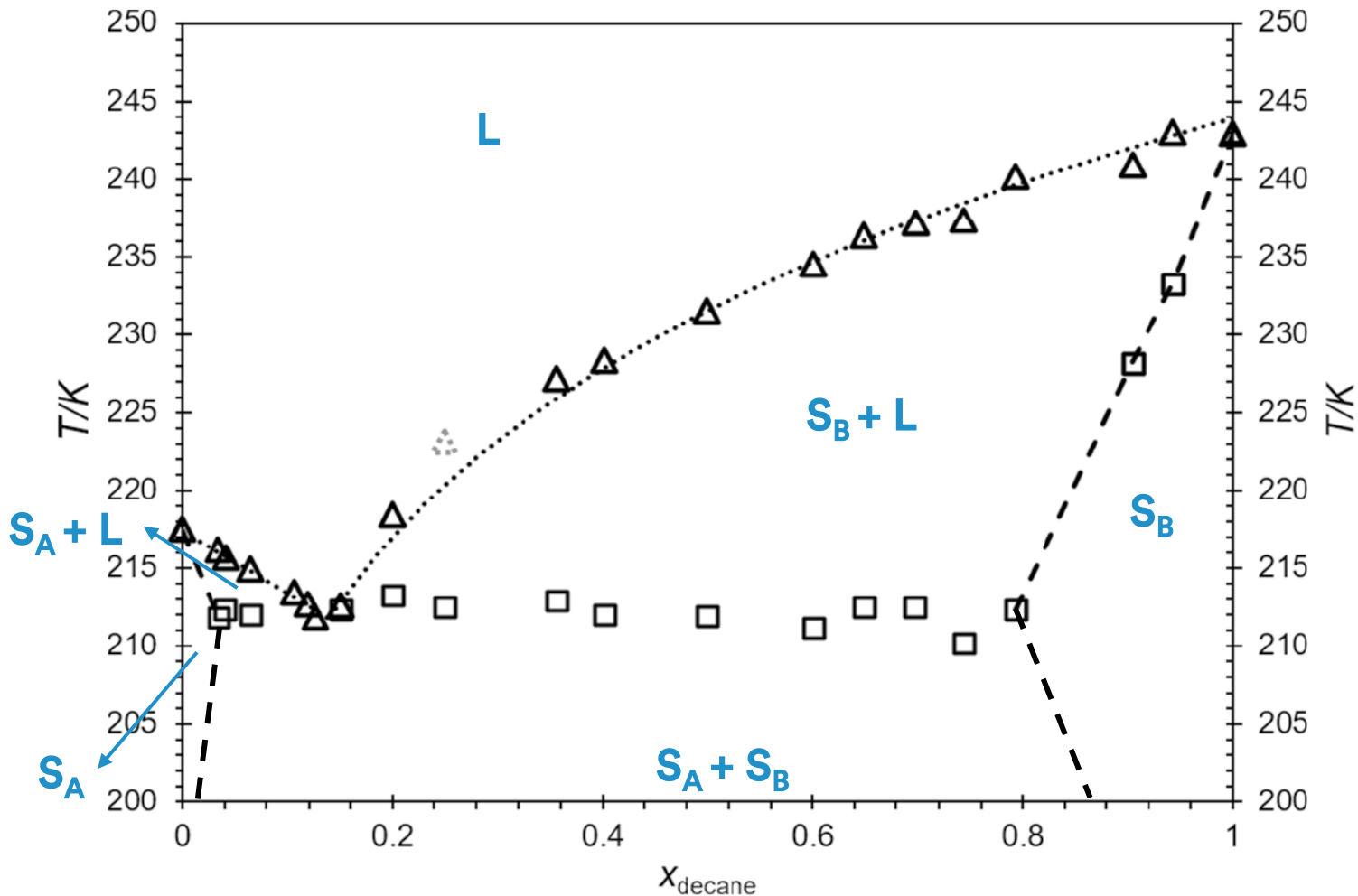


Fig. 1 Binary phase diagram for the binary alkane system C₈+C₁₀. Published in the International Journal of Thermophysics (IJT).

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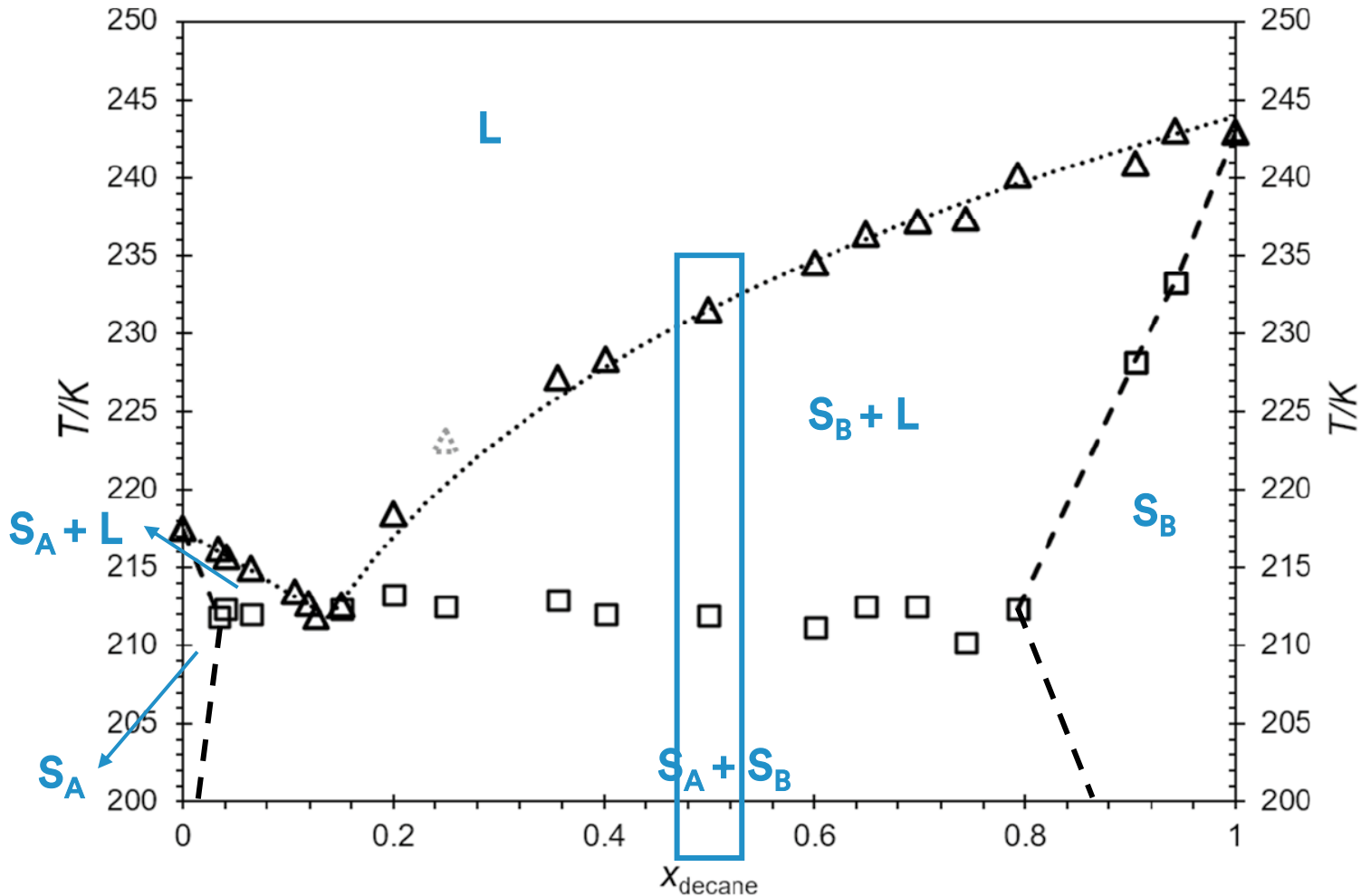


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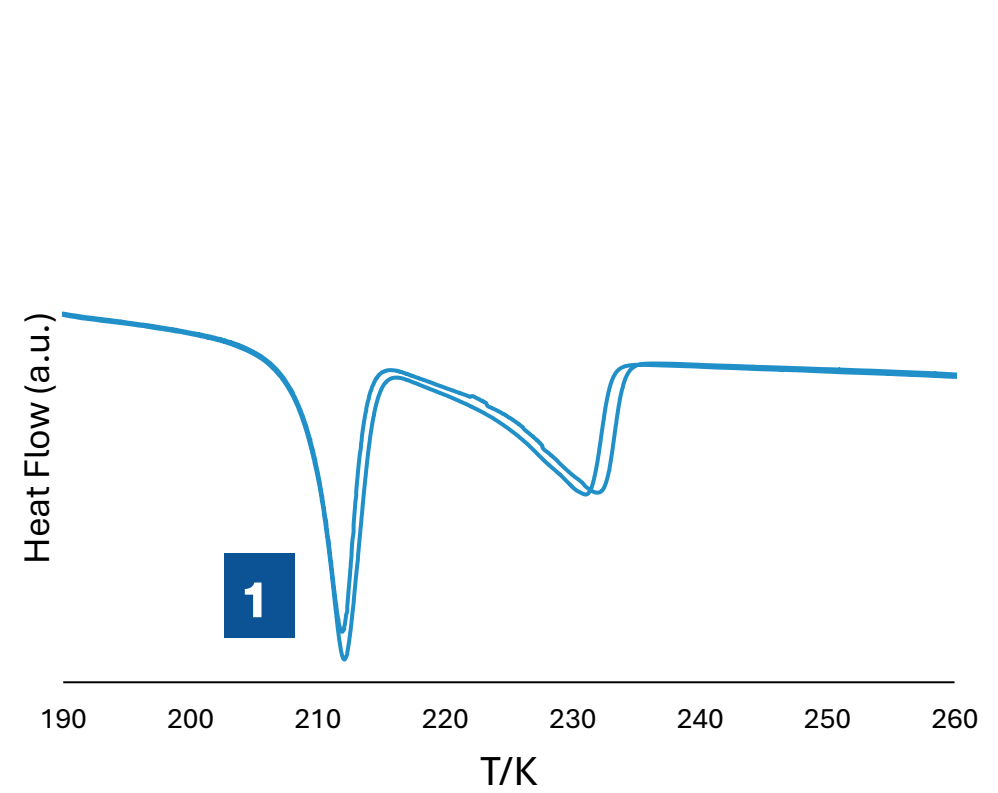
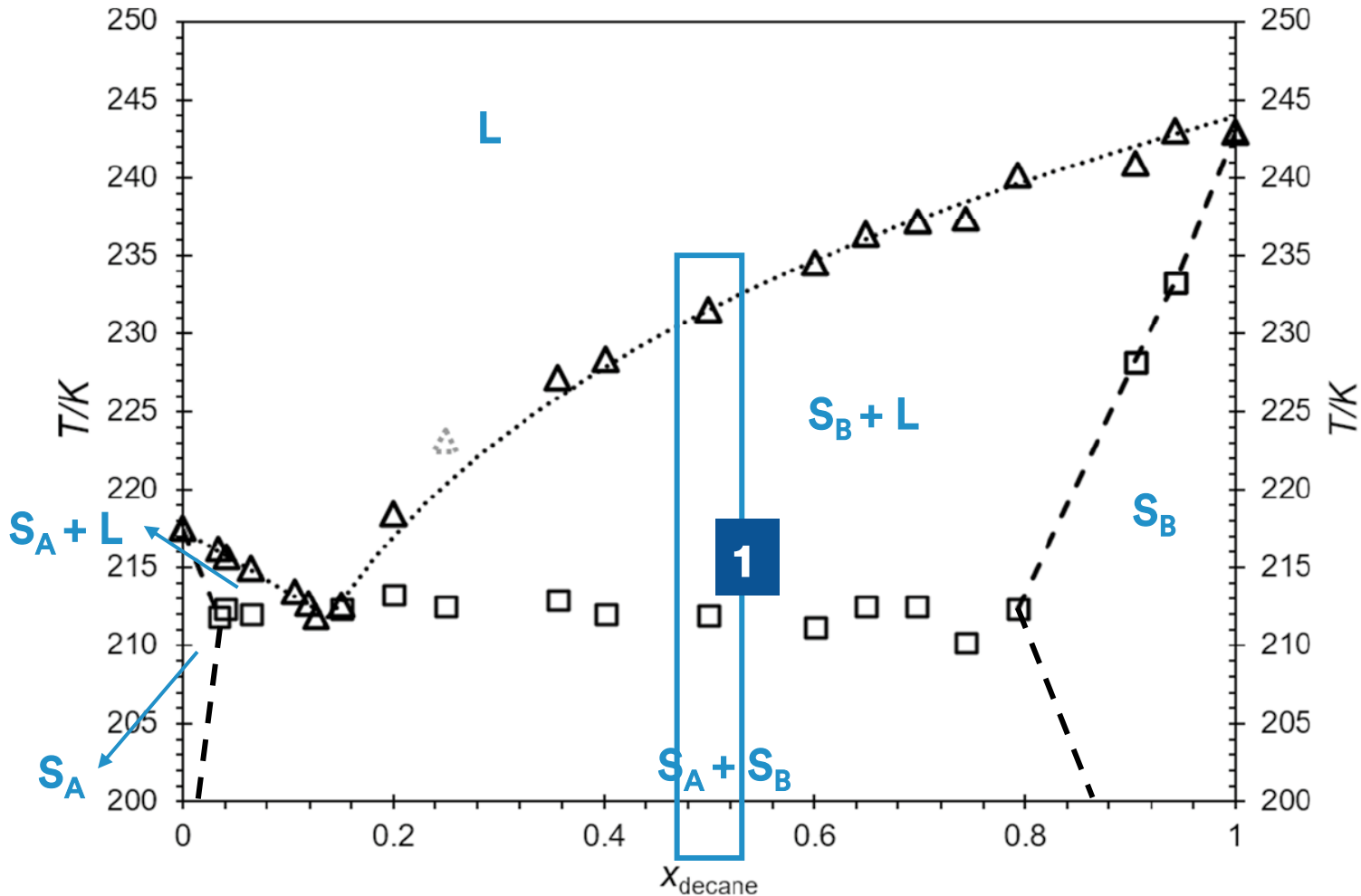


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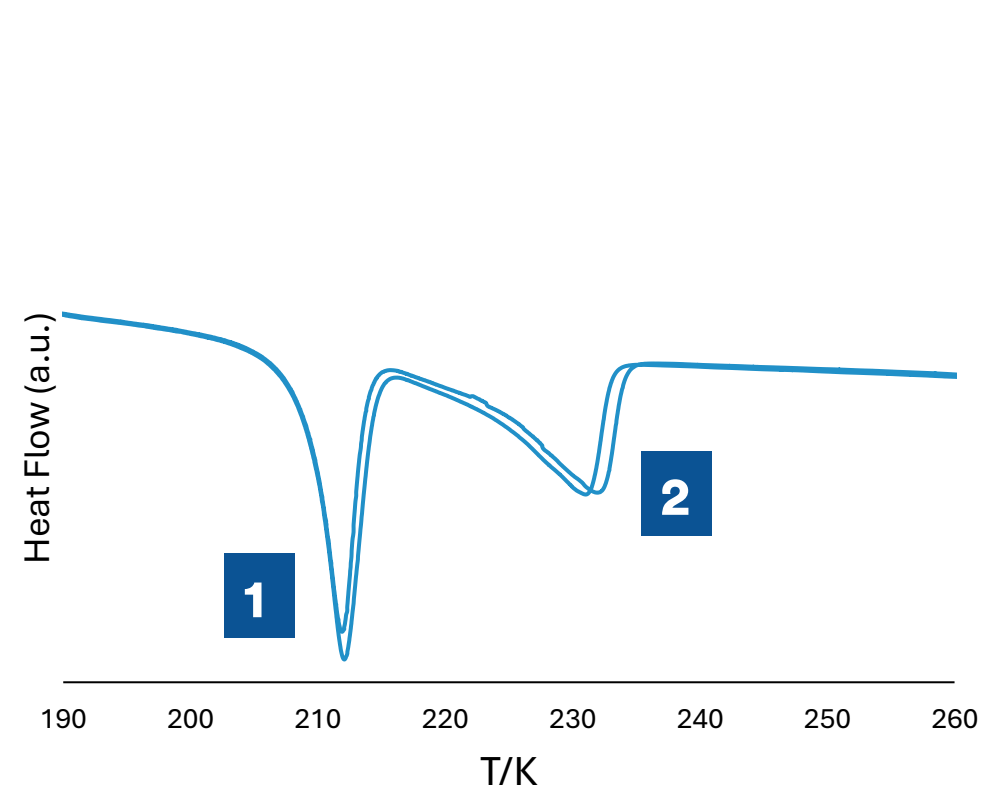
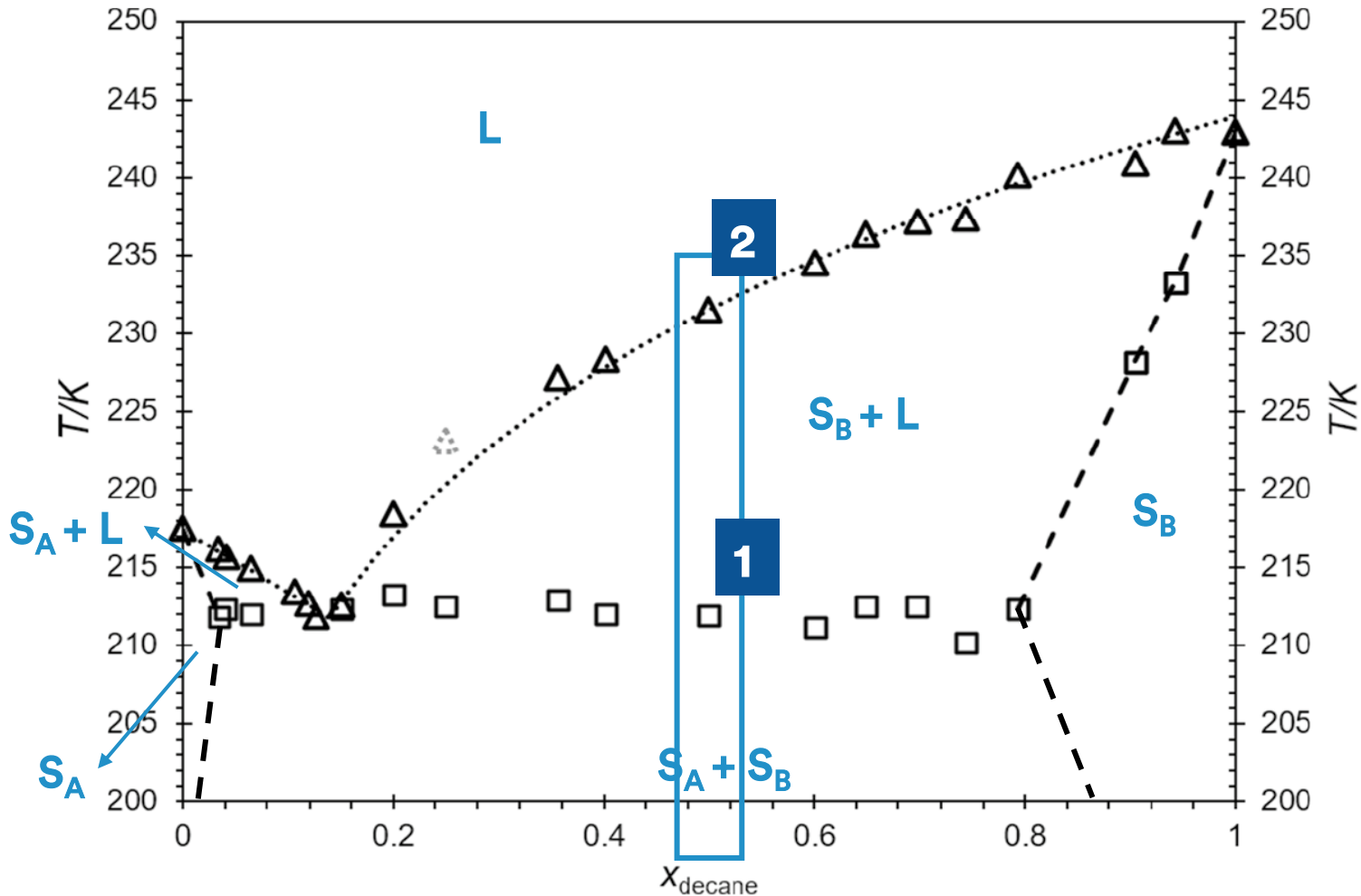


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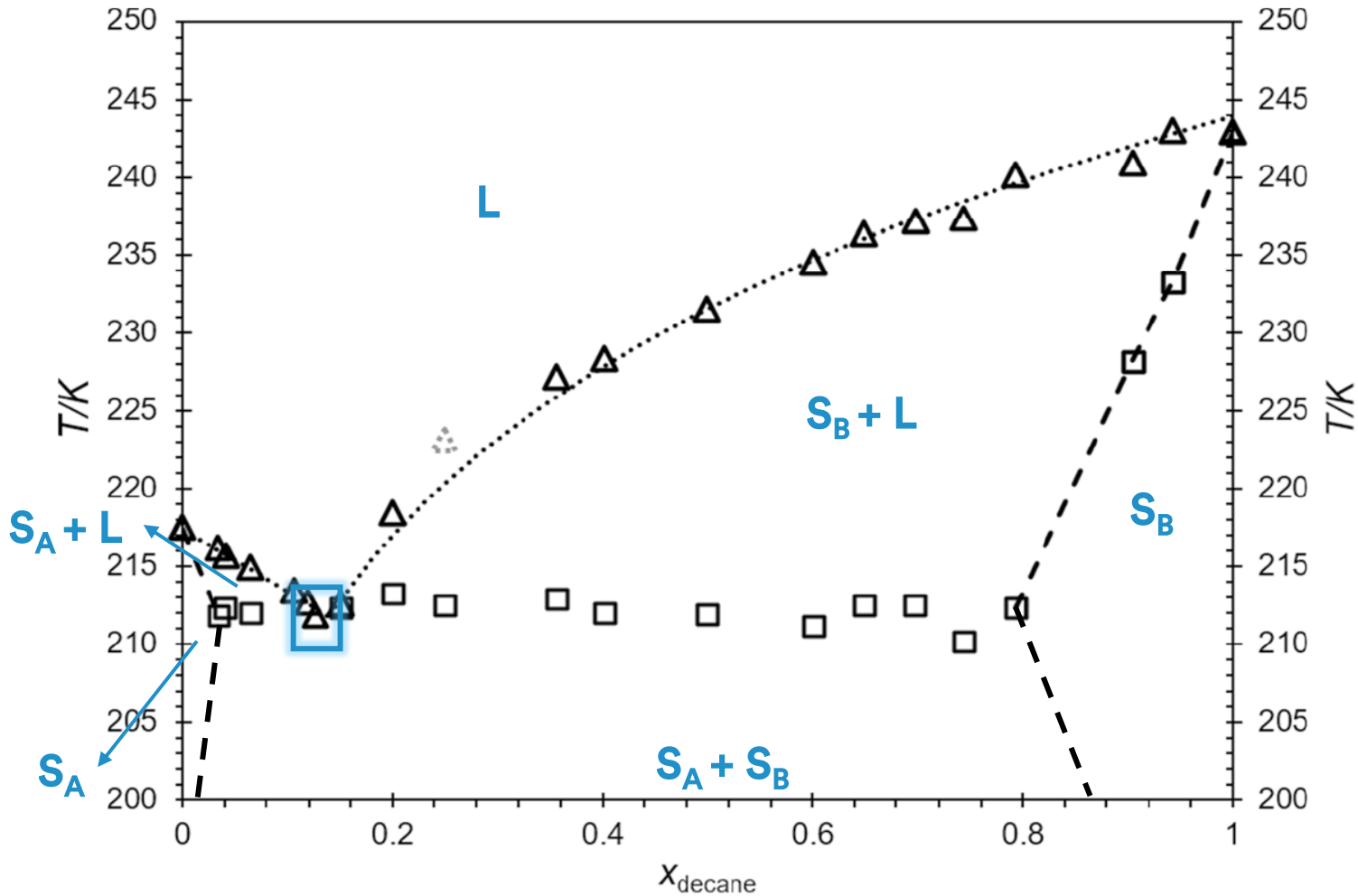


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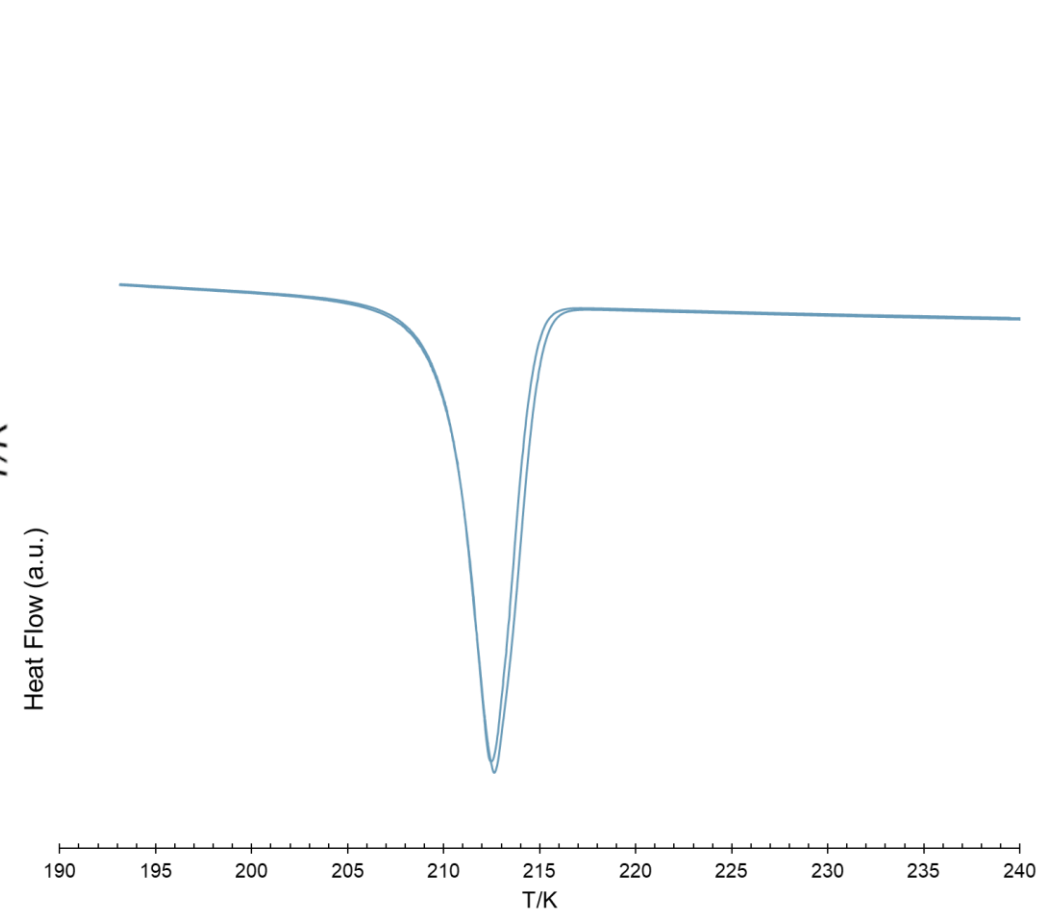
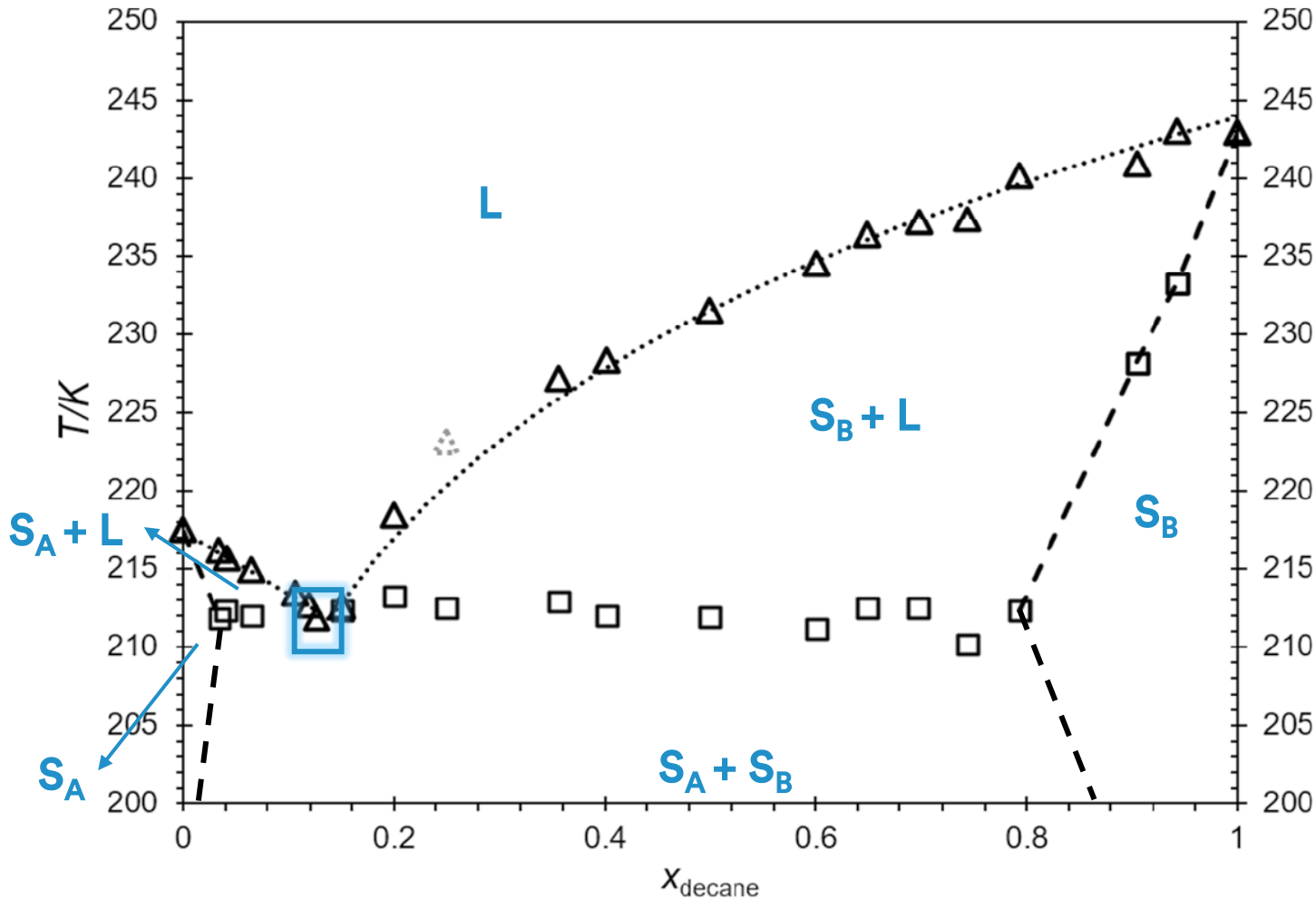


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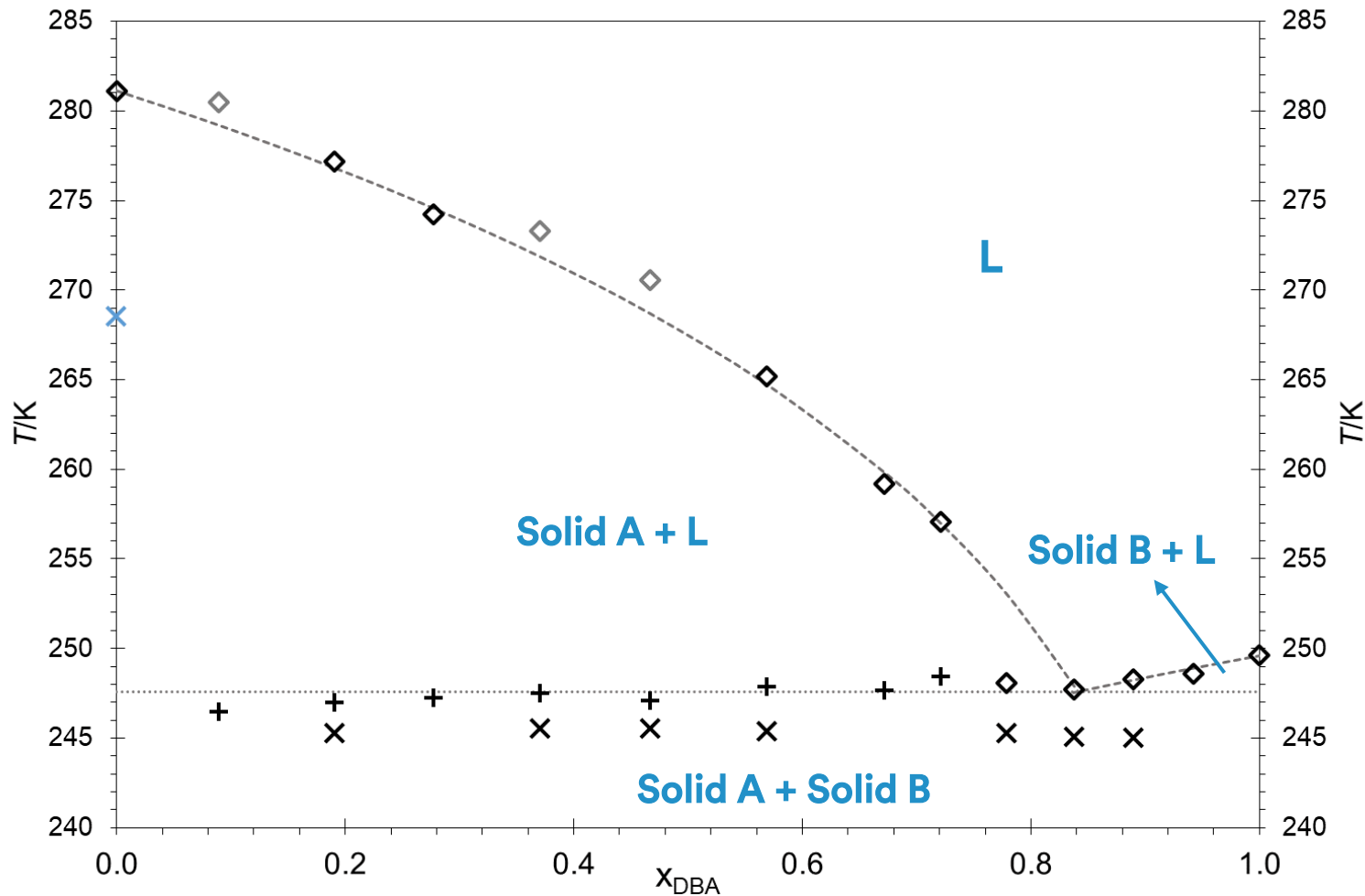


Fig. 2 Preliminary binary phase diagram for the binary adipate system Dimethyl + Dibutyl.

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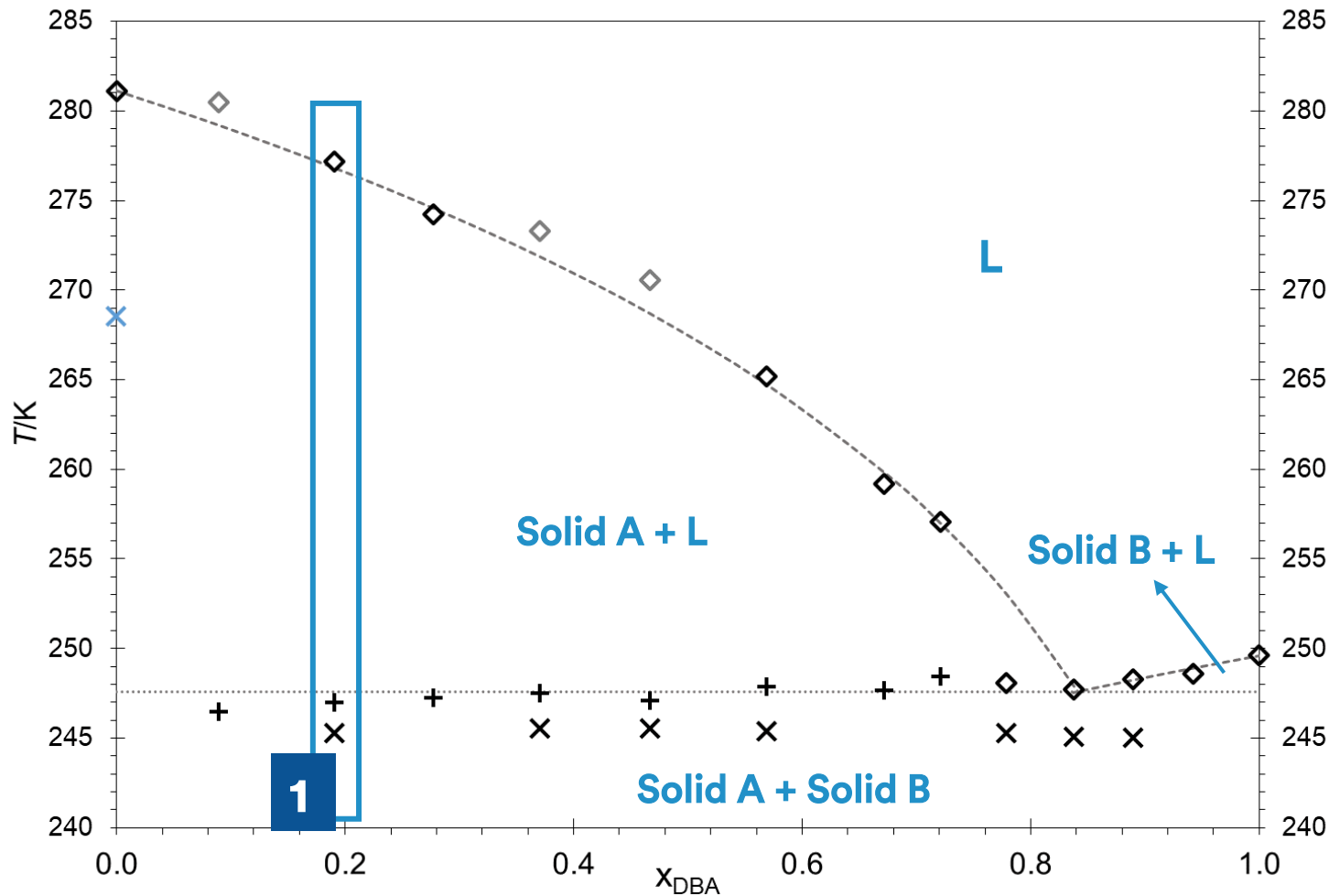
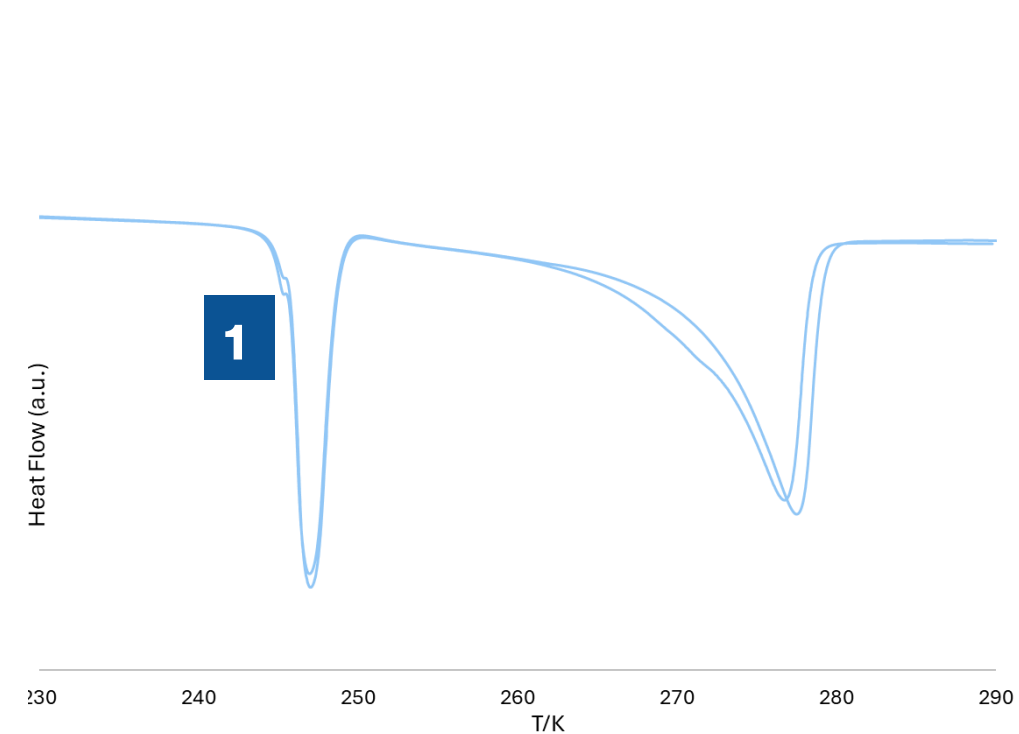


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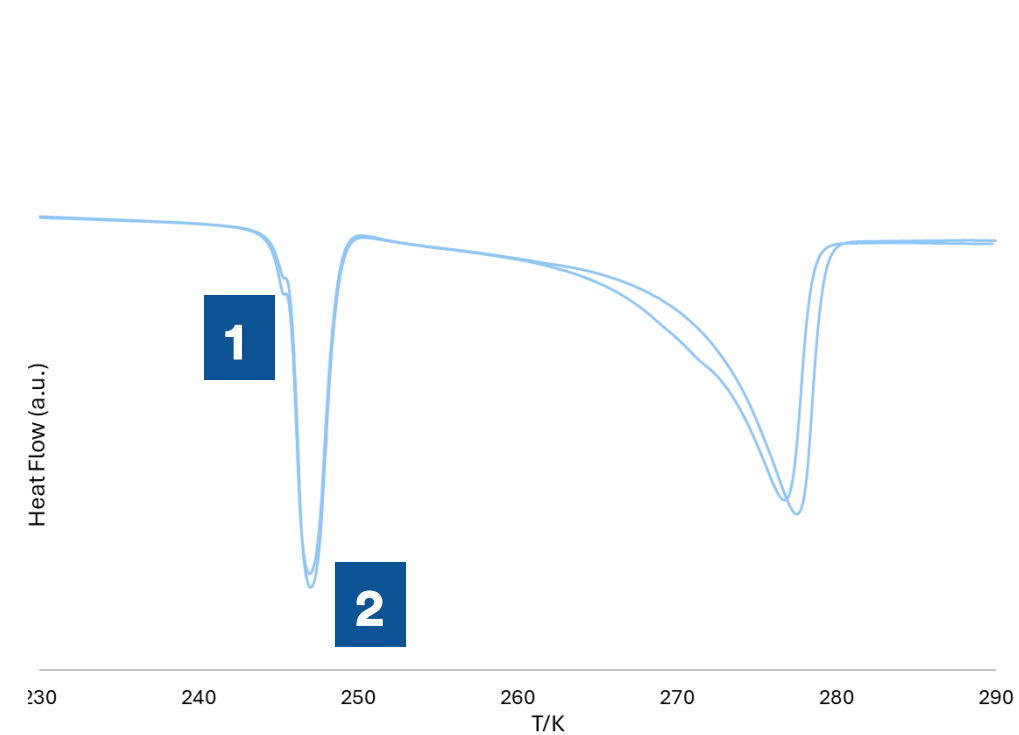
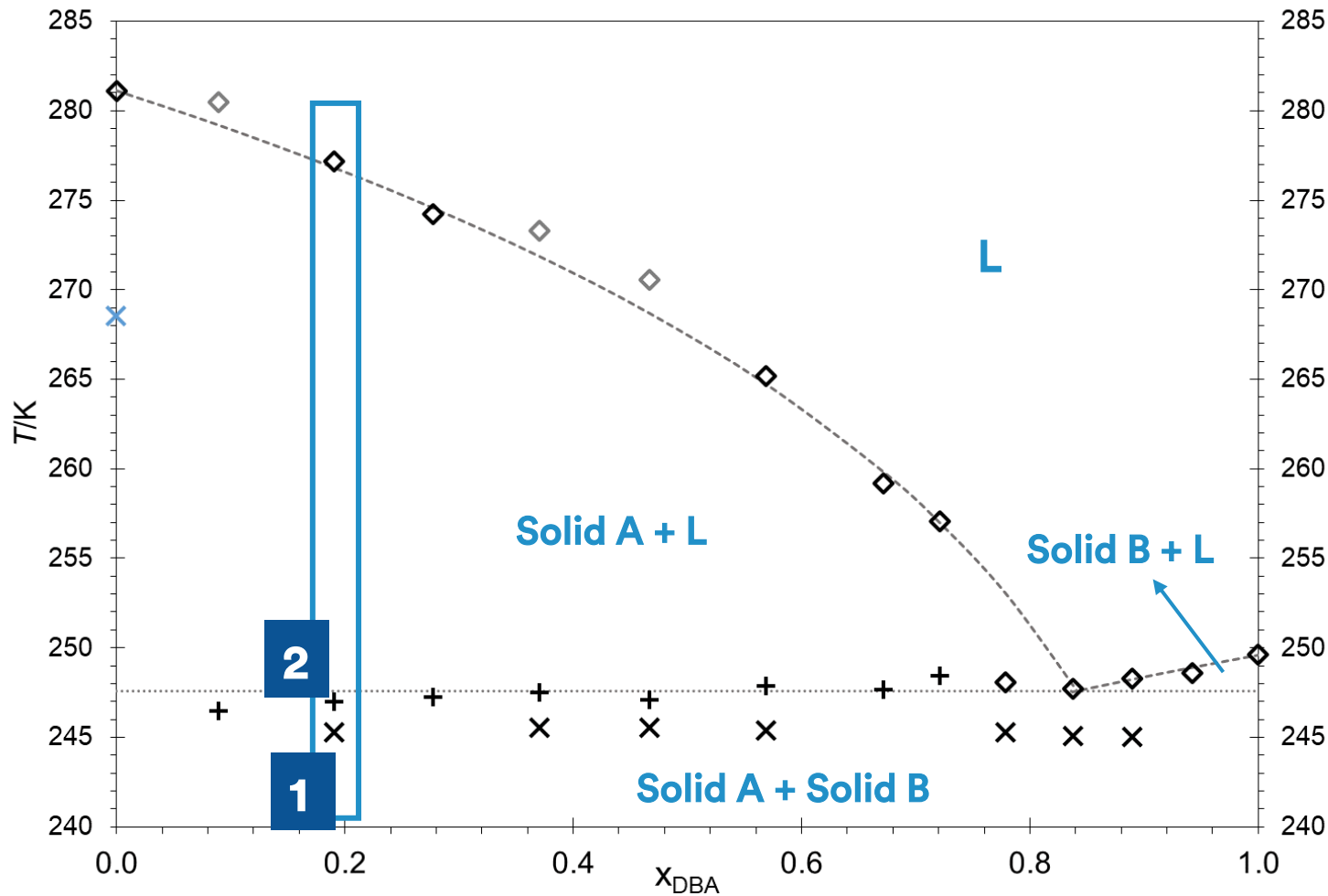


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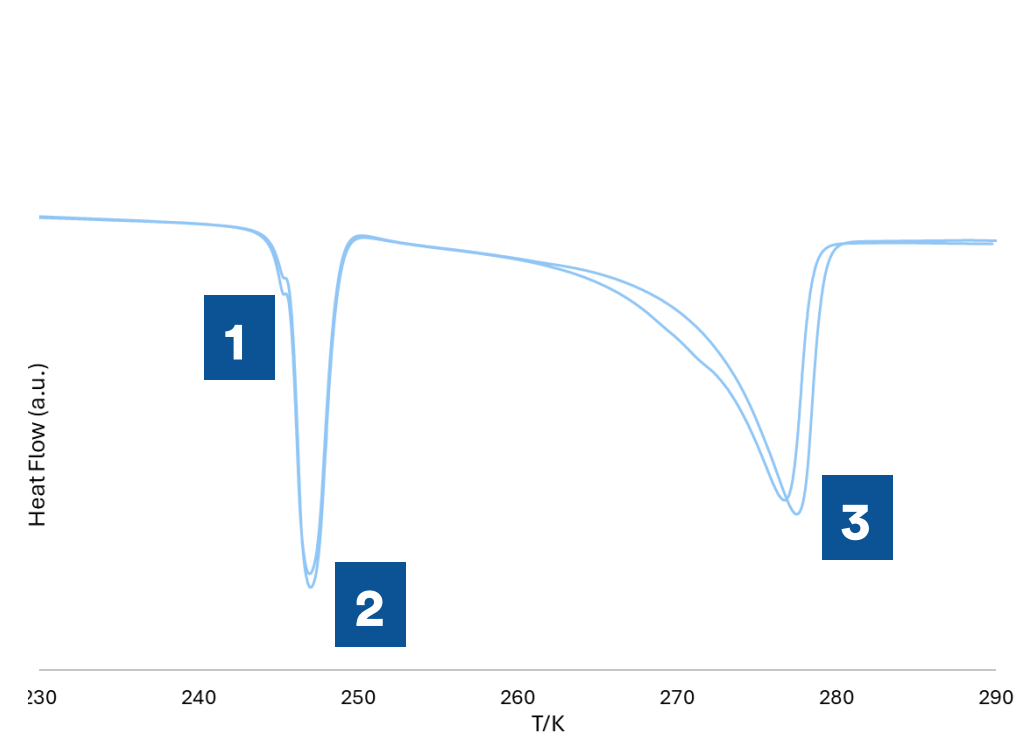
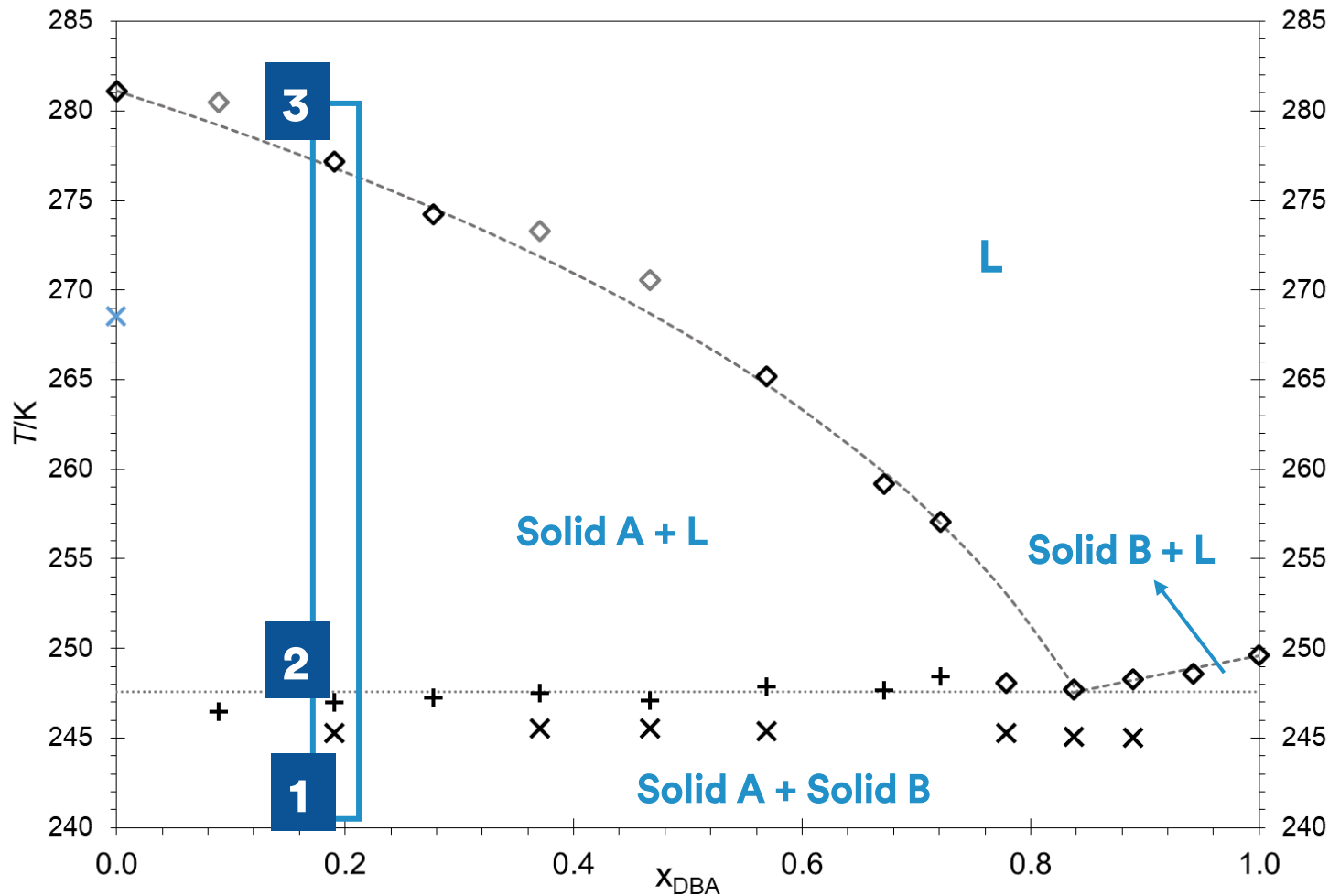


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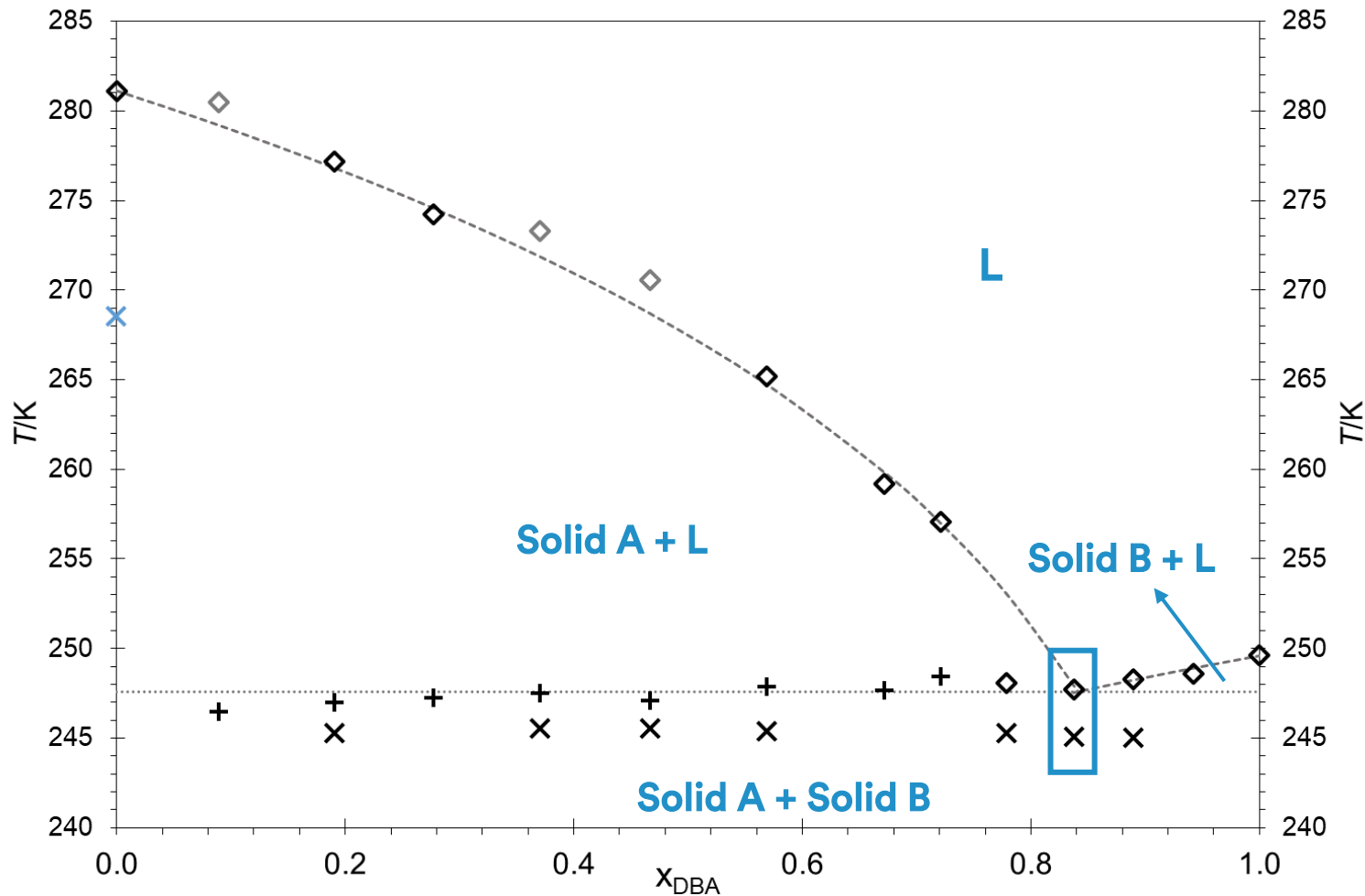


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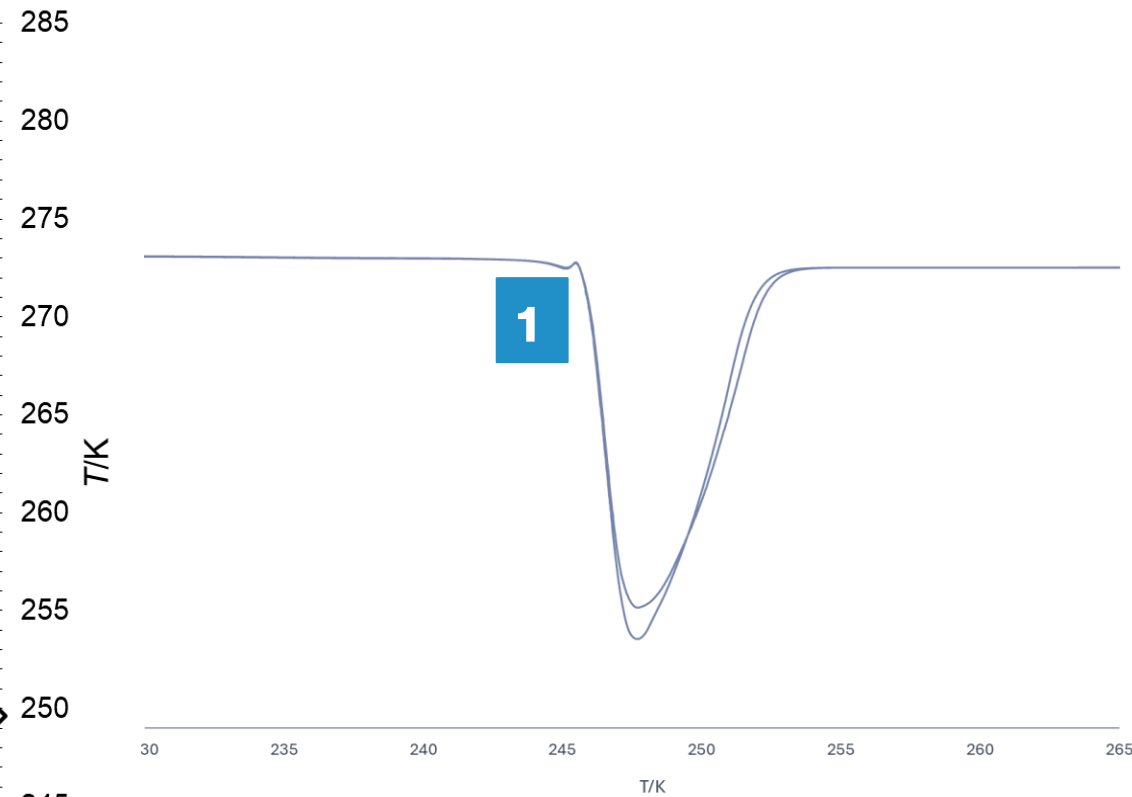
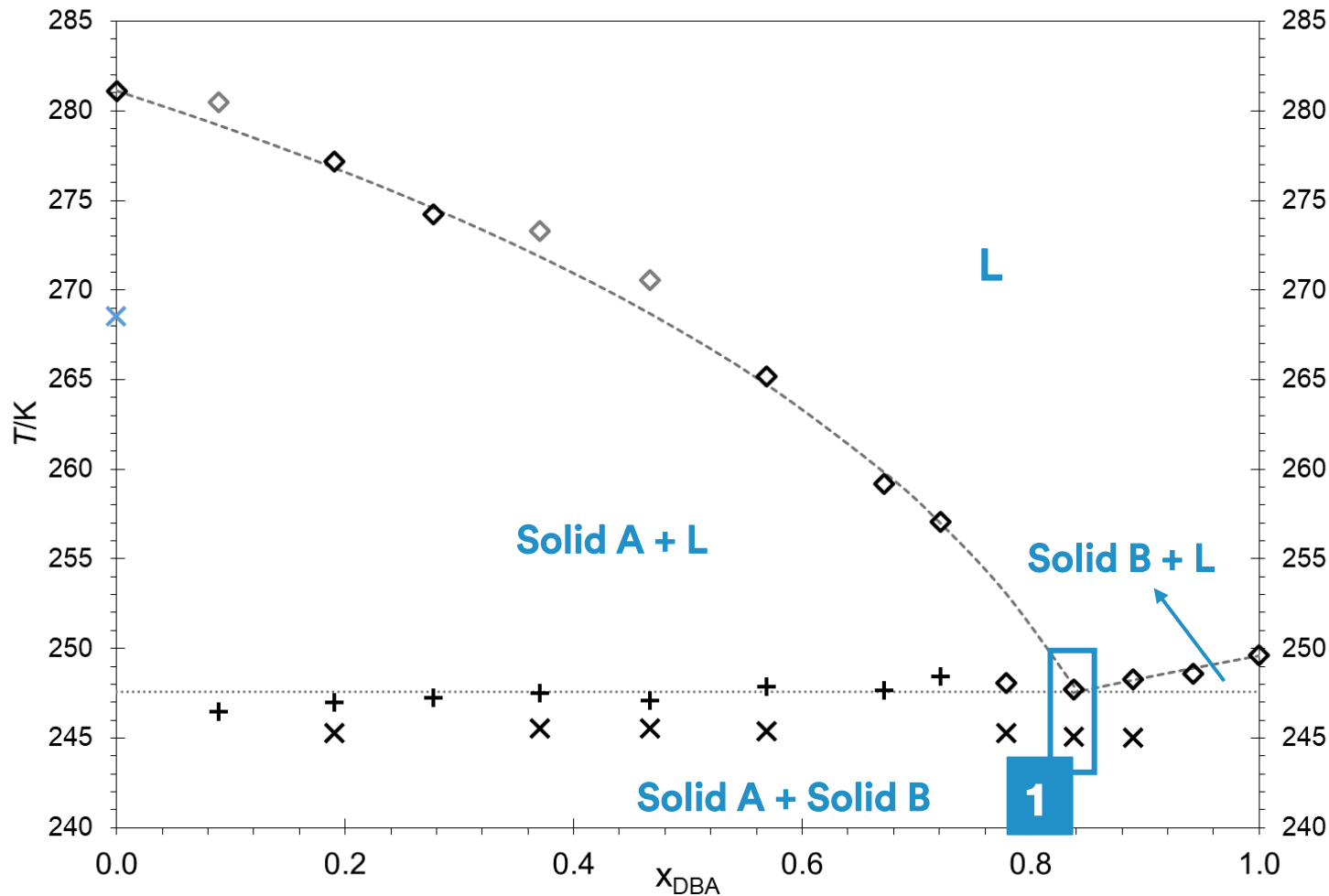


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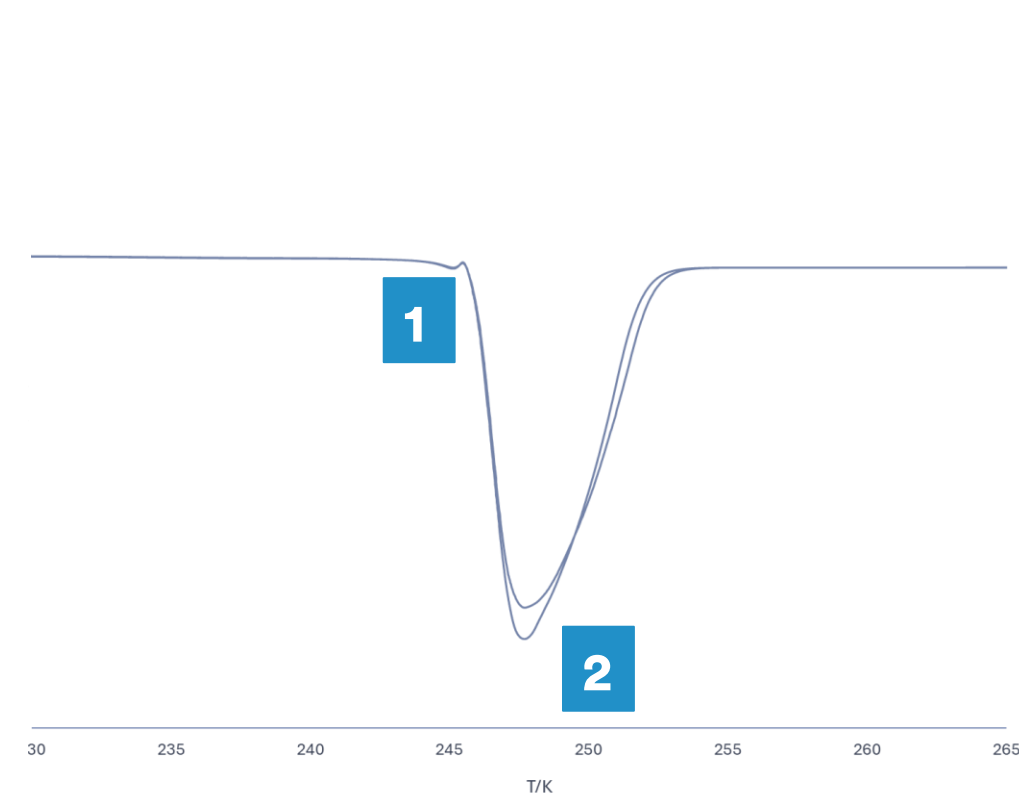
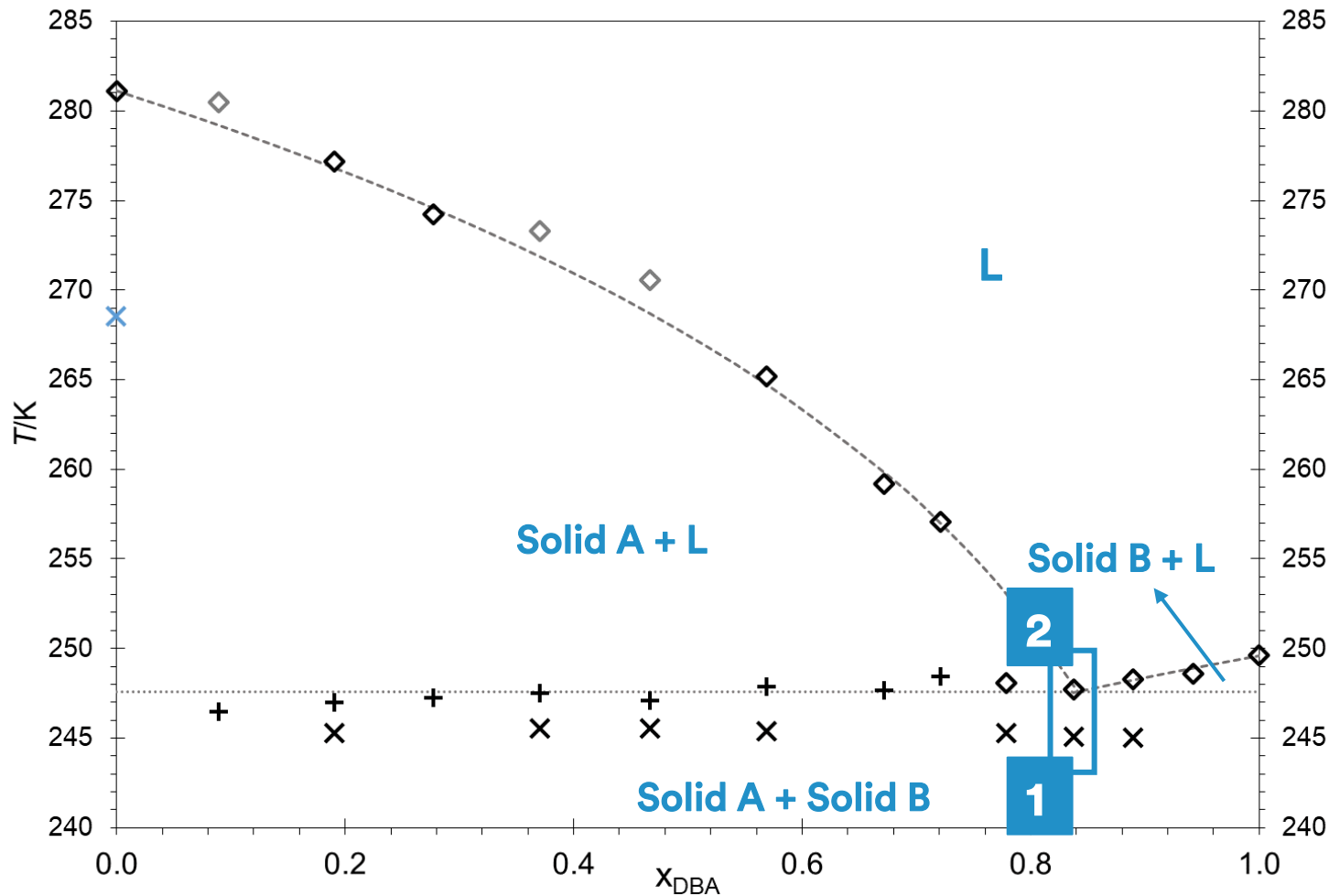


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HSPM Images: Non-isomorphous eutectic (dimethyl+dibutyl adipates)

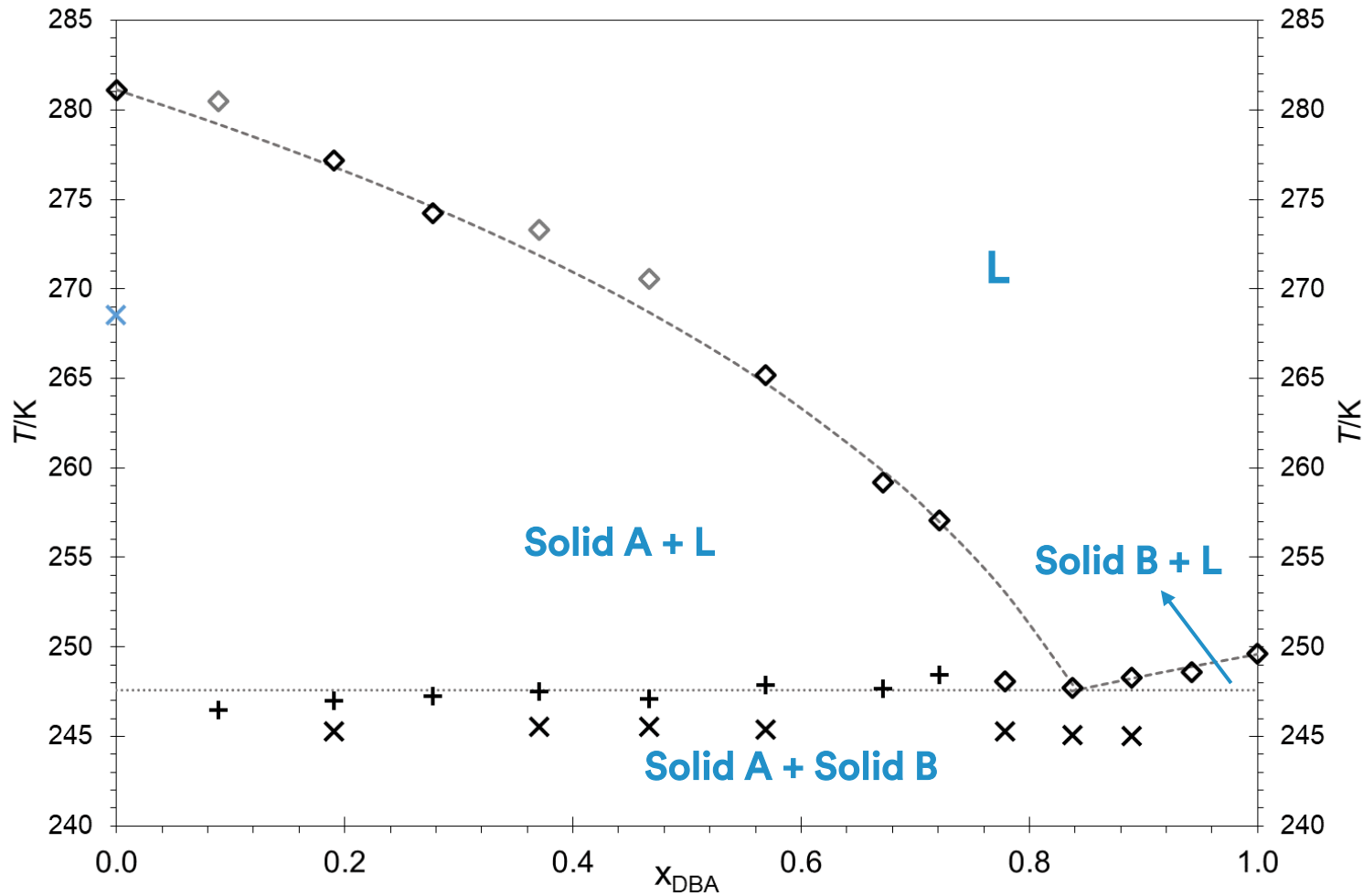


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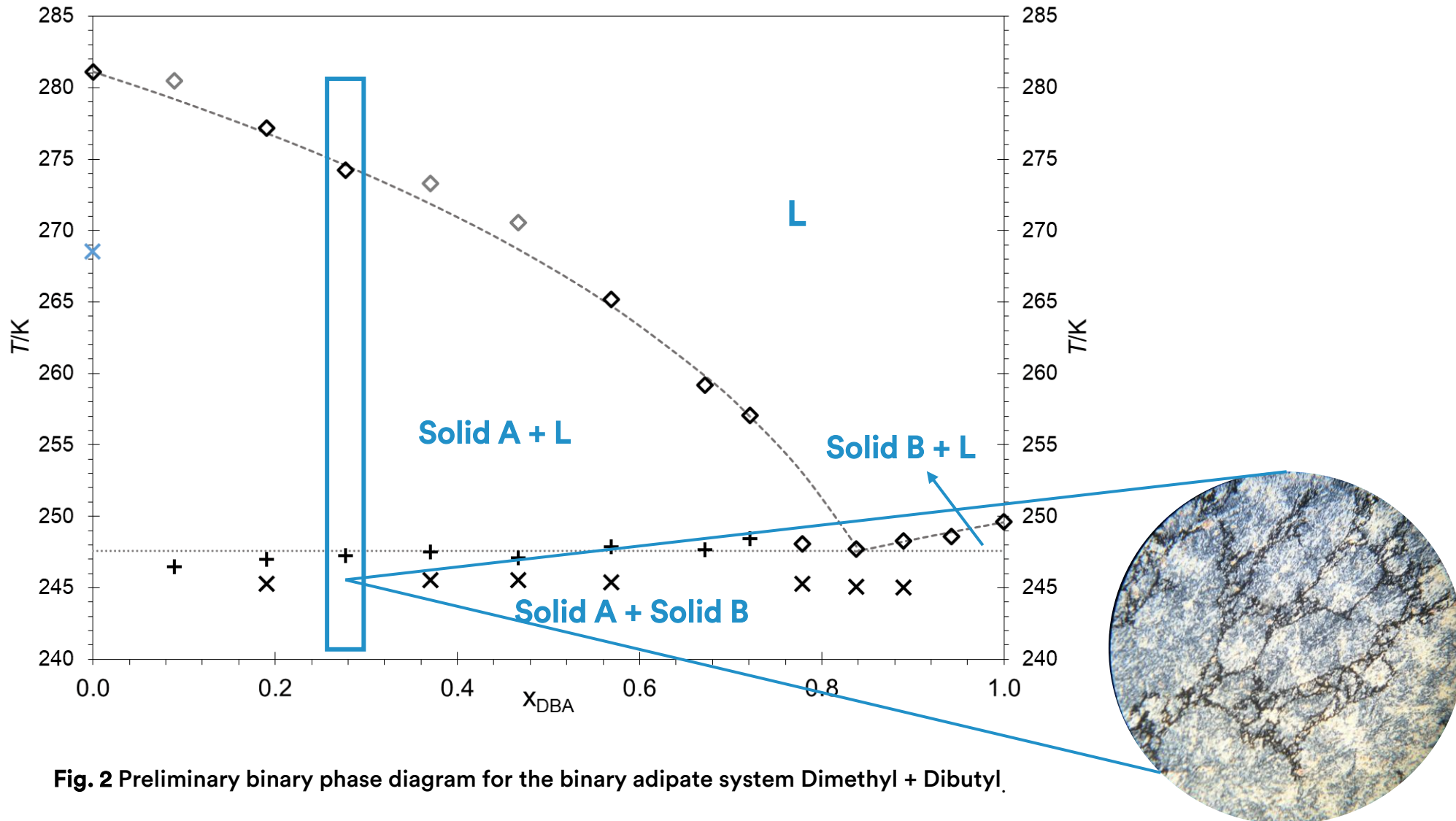


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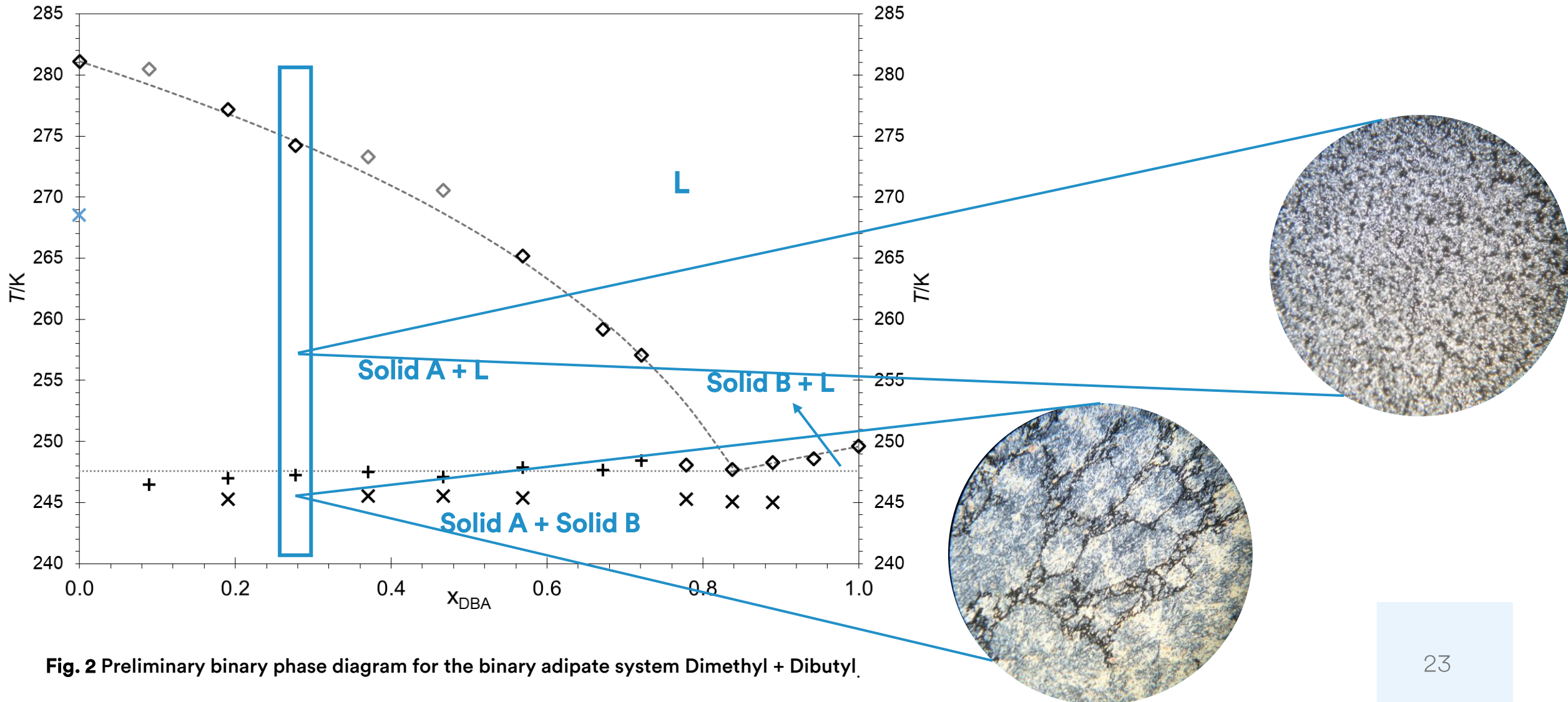


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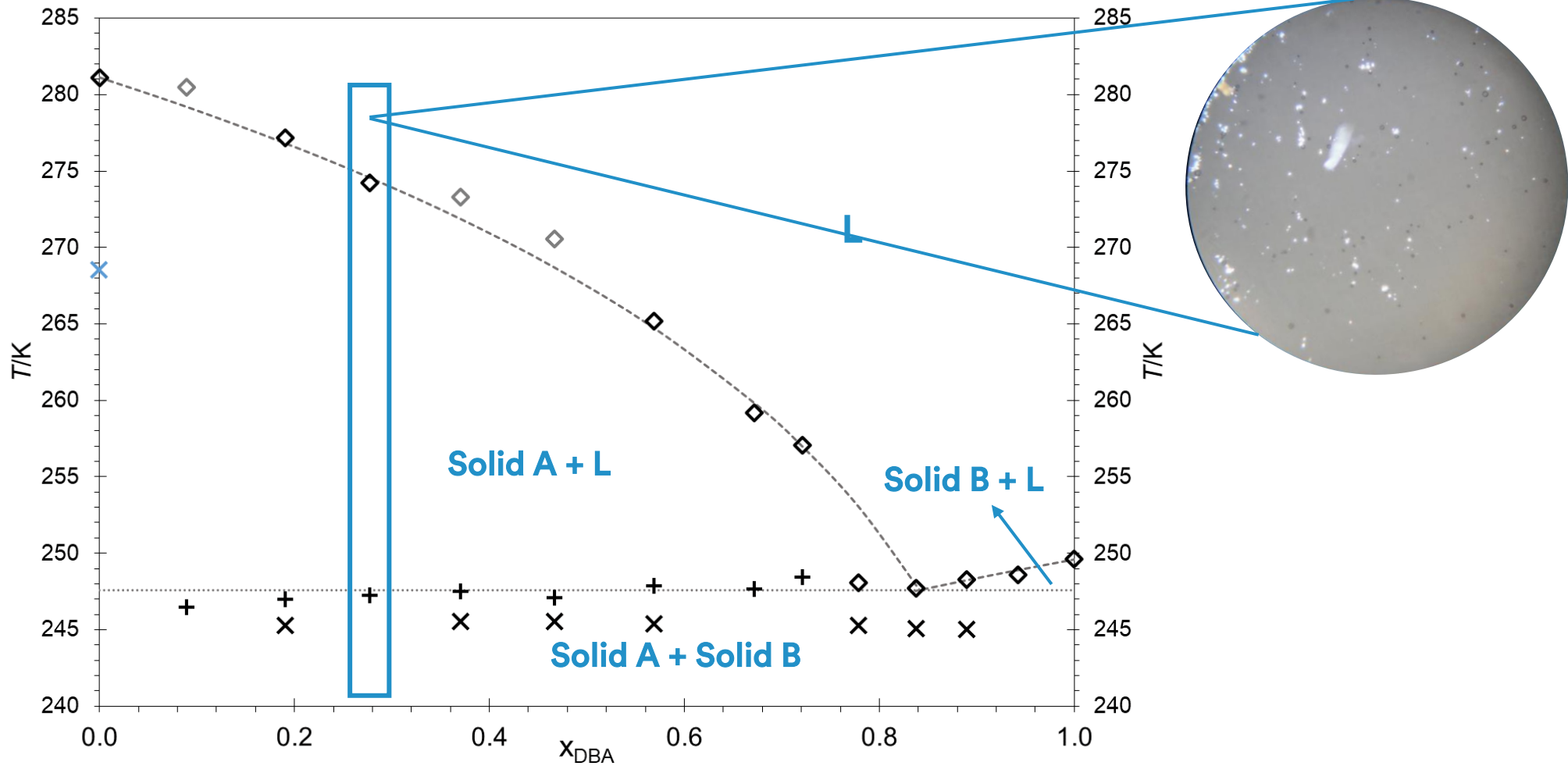


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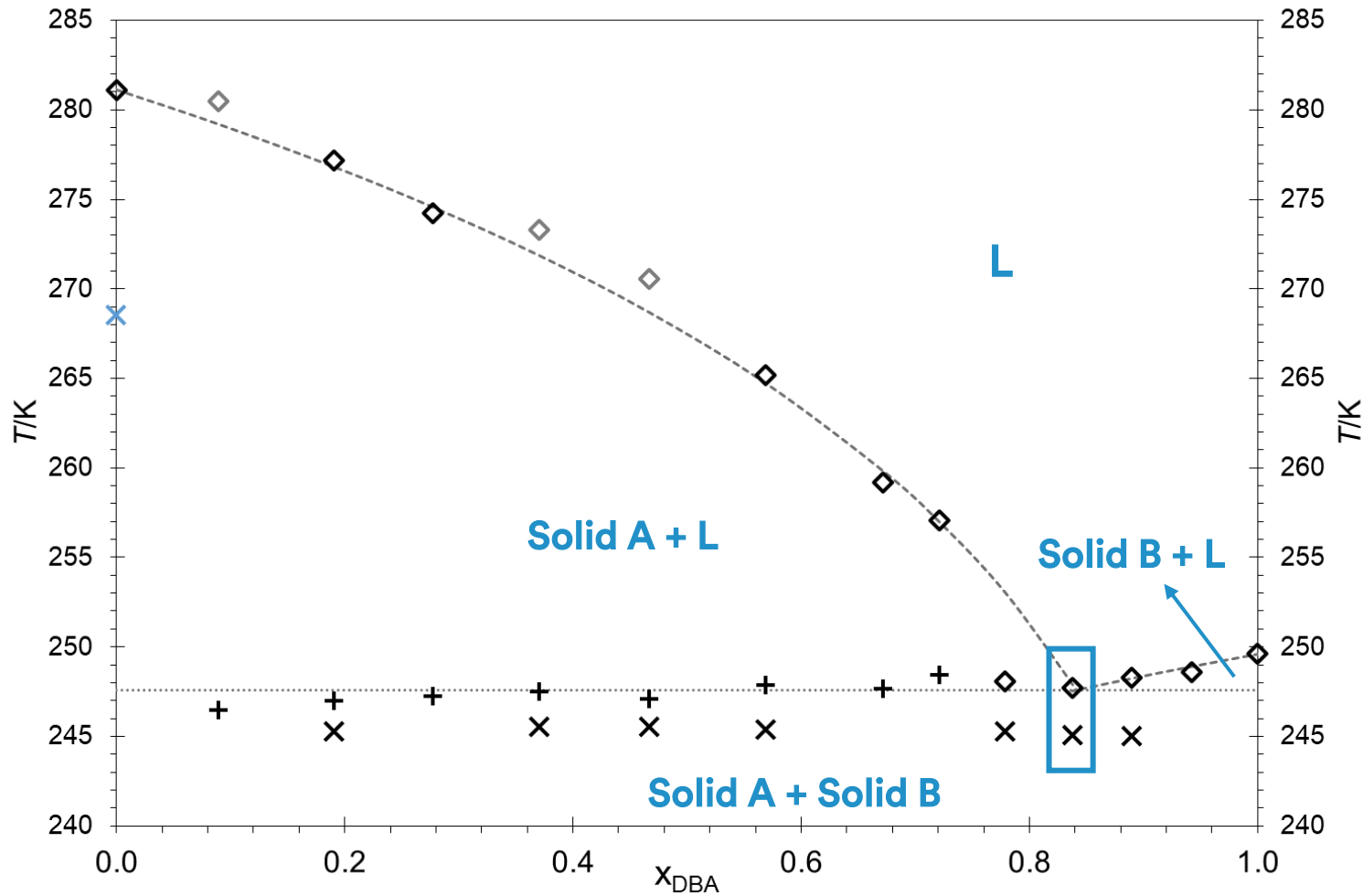


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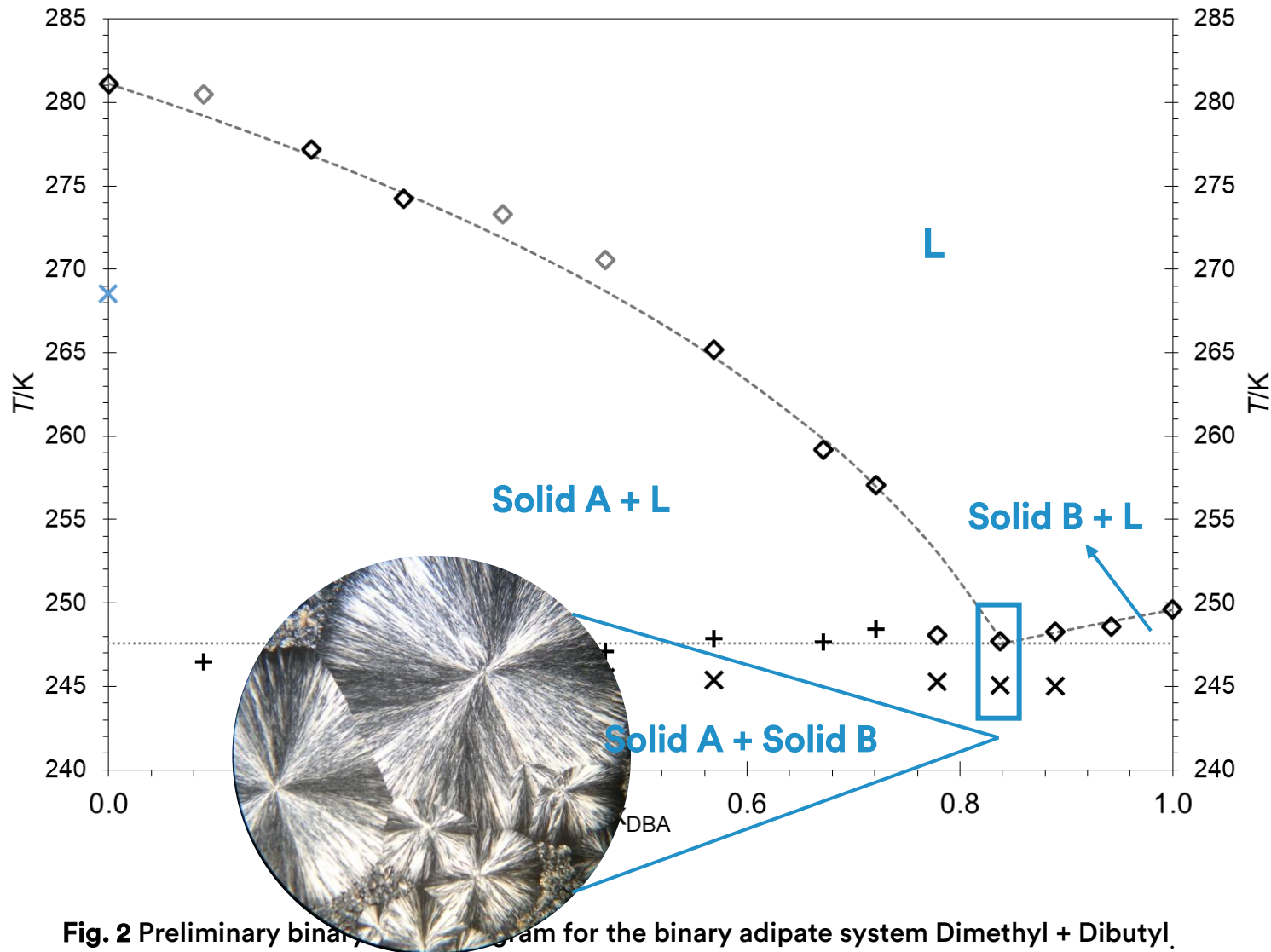


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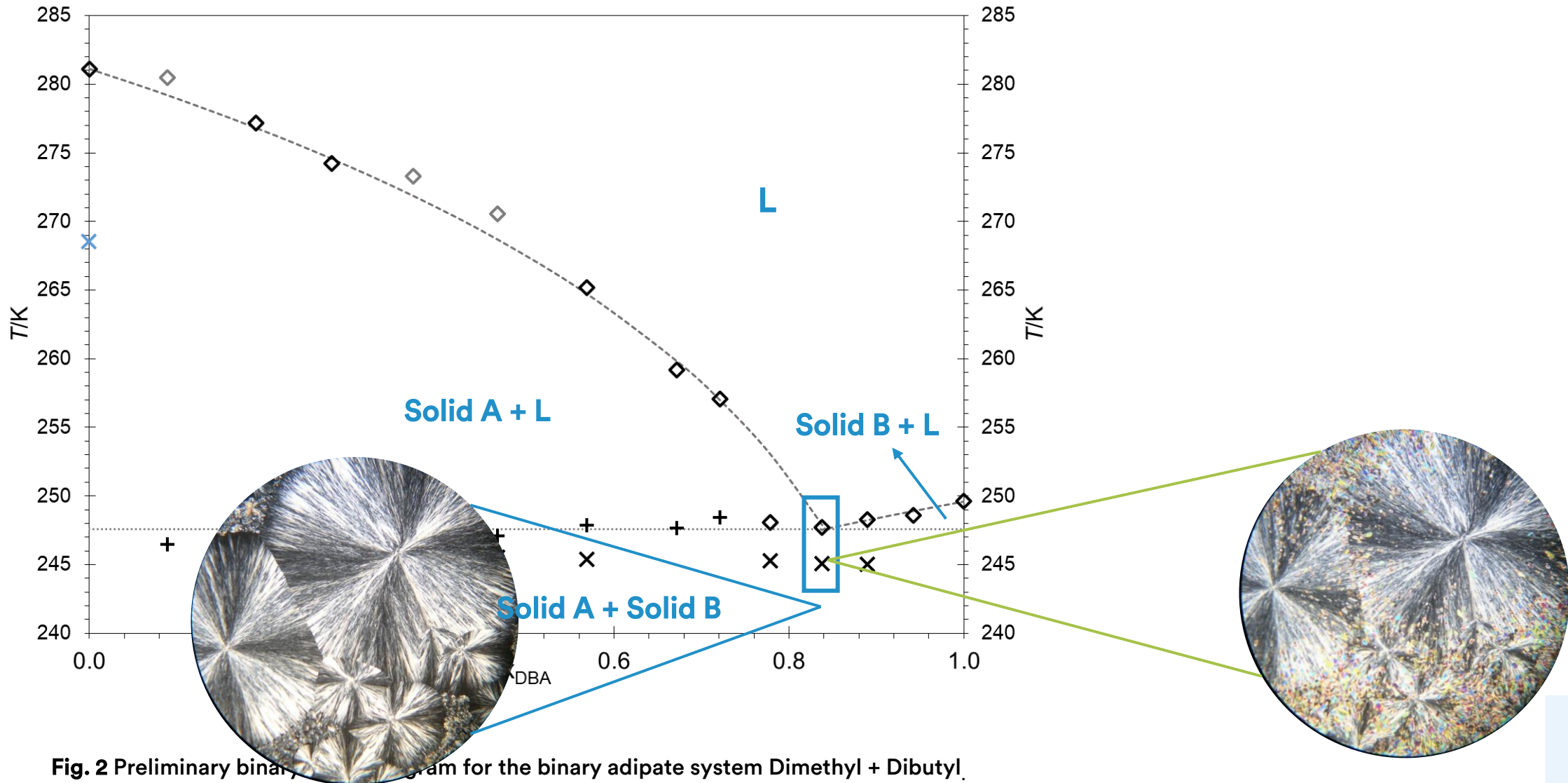


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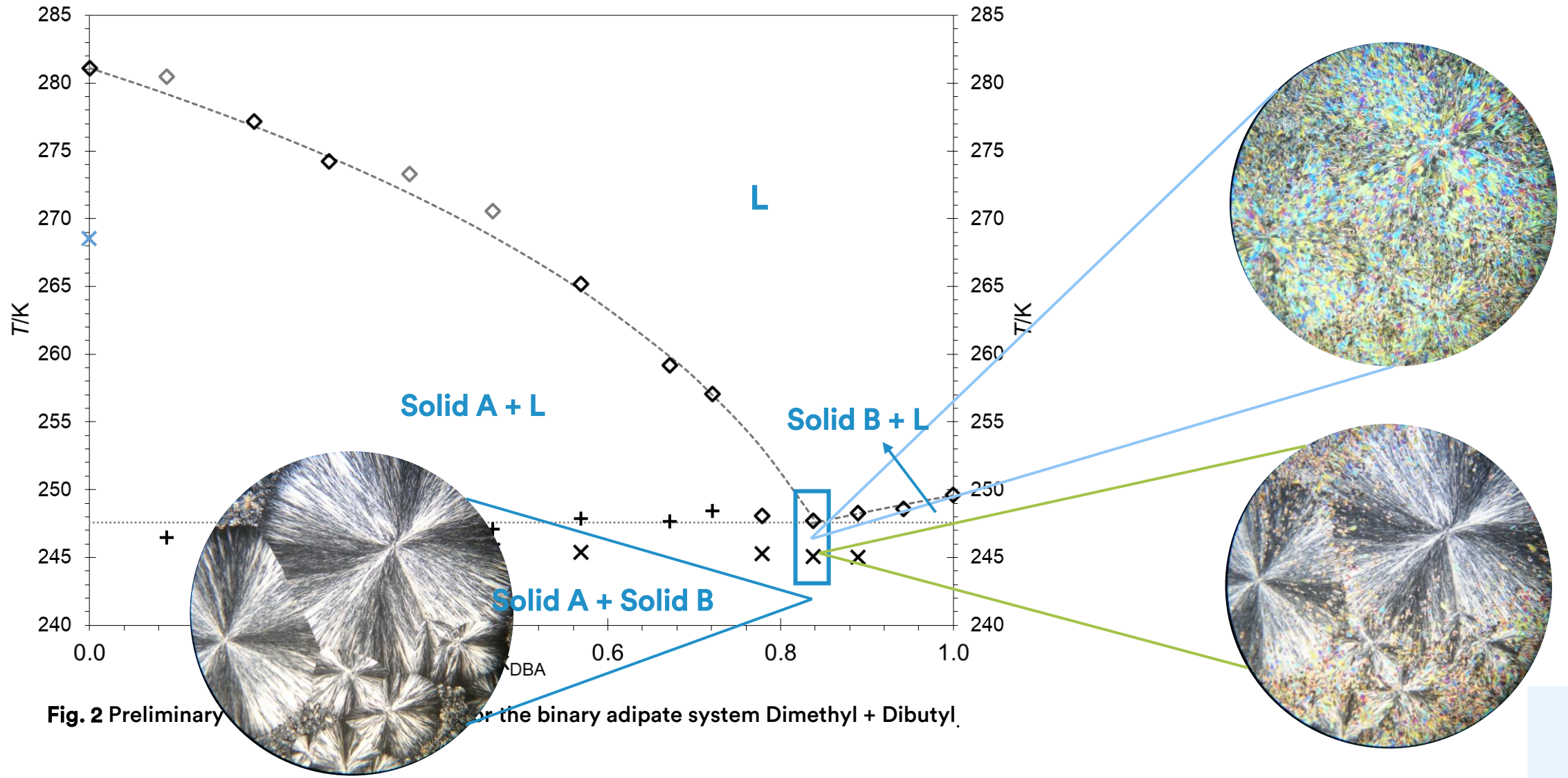
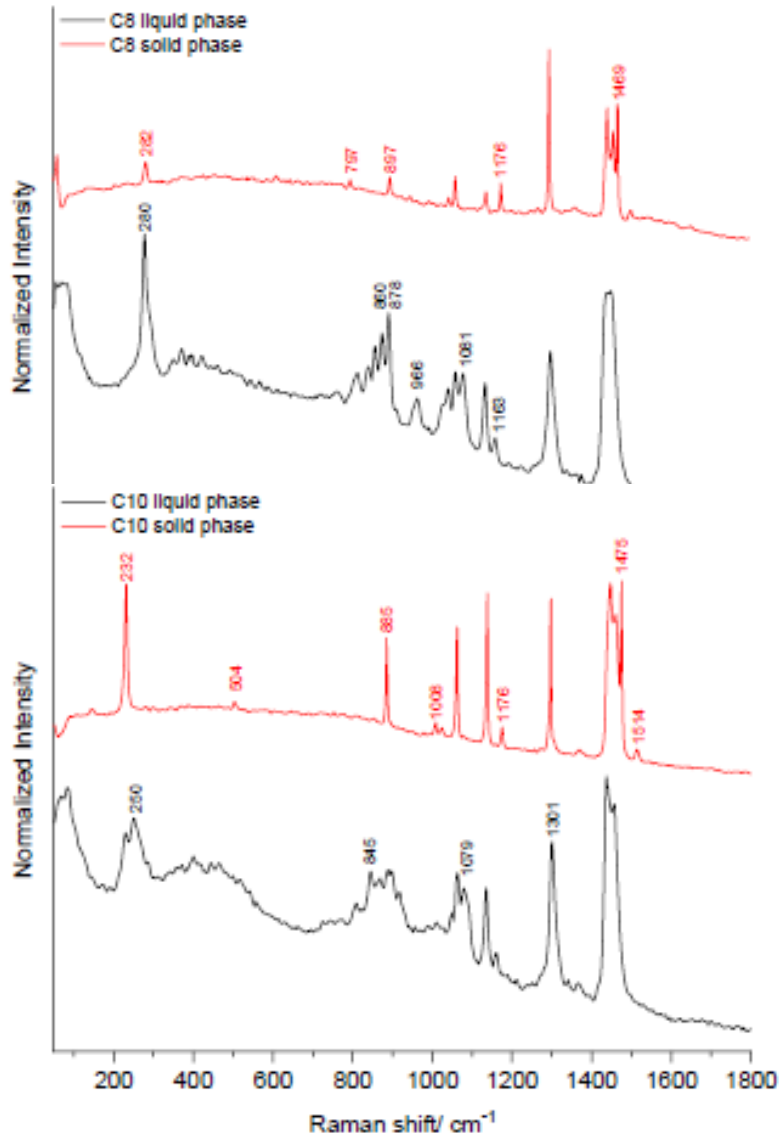


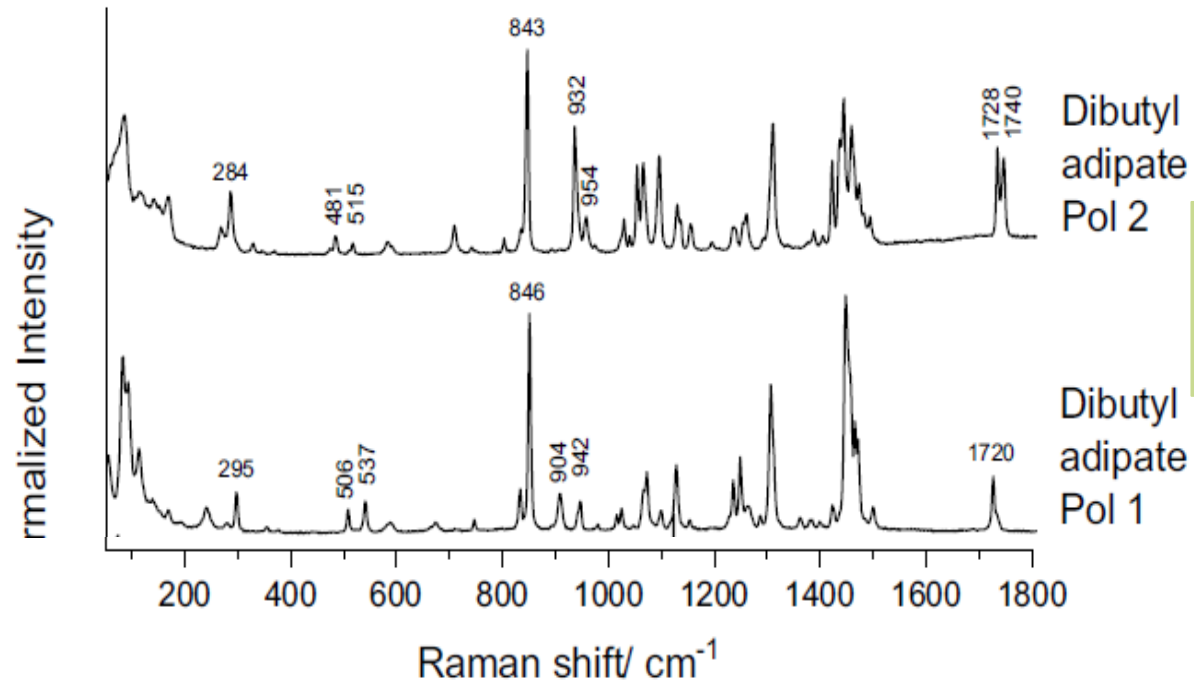
Fig. 2 Preliminary phase diagram for the binary adipate system Dimethyl + Dibutyl

Raman Spectroscopy: Pure compounds



1st step:

Raman spectra for pure compounds both in liquid and solid phases

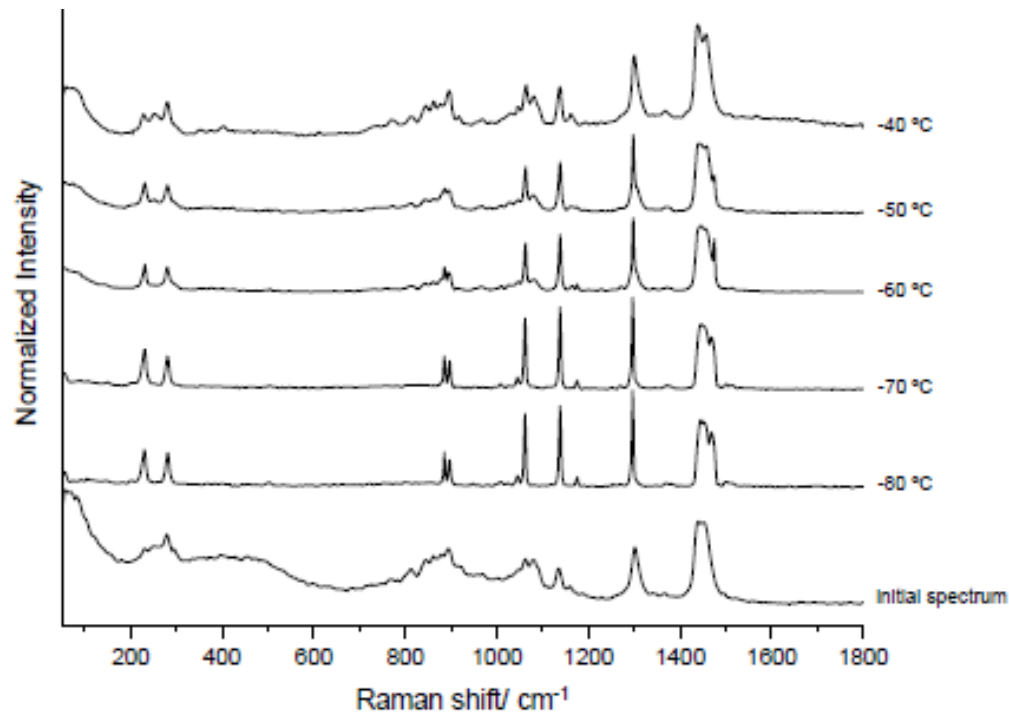


Distinguish
different
polymorphs

Raman Spectroscopy: Binary Mixtures

2nd step:

Raman spectra for binary mixtures with temperature-variation



Partially isomorphous eutectic (C₈ + C₁₀)



The marker bands of both compounds for solid/liquid phase appear at the same time

Non-isomorphous eutectic (dimethyl+dibutyl adipates)



The marker bands of both compounds for solid/liquid phase appear separately

ENHANCING THERMAL ENERGY STORAGE

Alkanes



Material	Relative Value
Alkanes	~75%
Adipates	~95%

Adipates

ENHANCING THERMAL ENERGY STORAGE

Alkanes

-30 °C

-65 °C

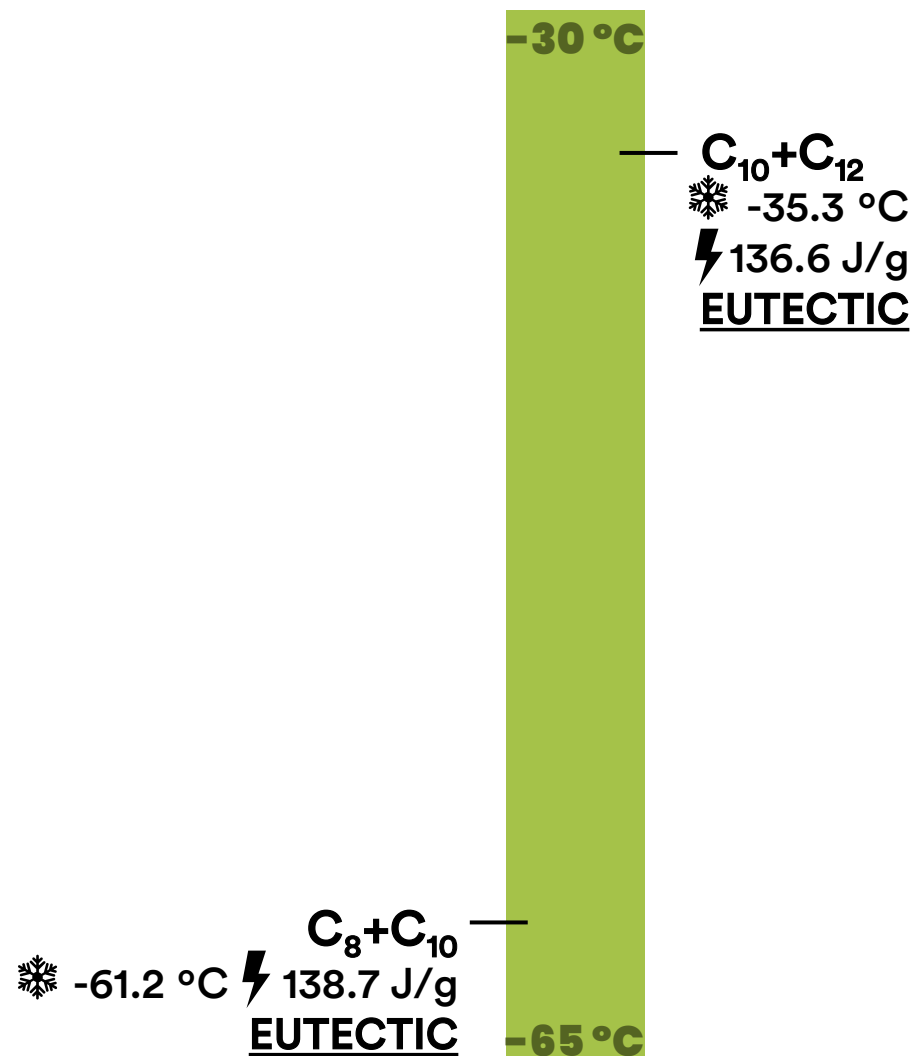
-15 °C

-30 °C

Adipates

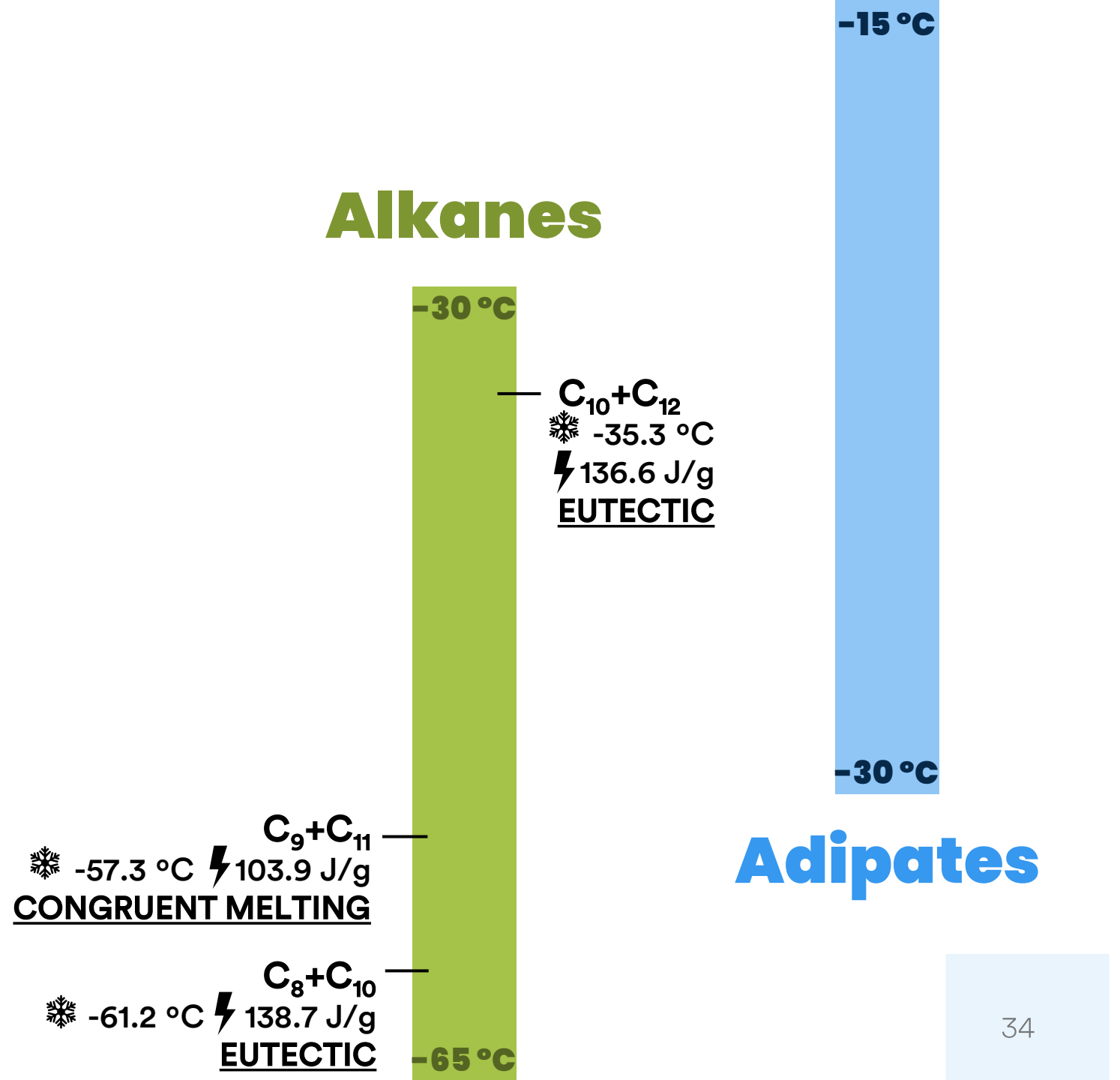
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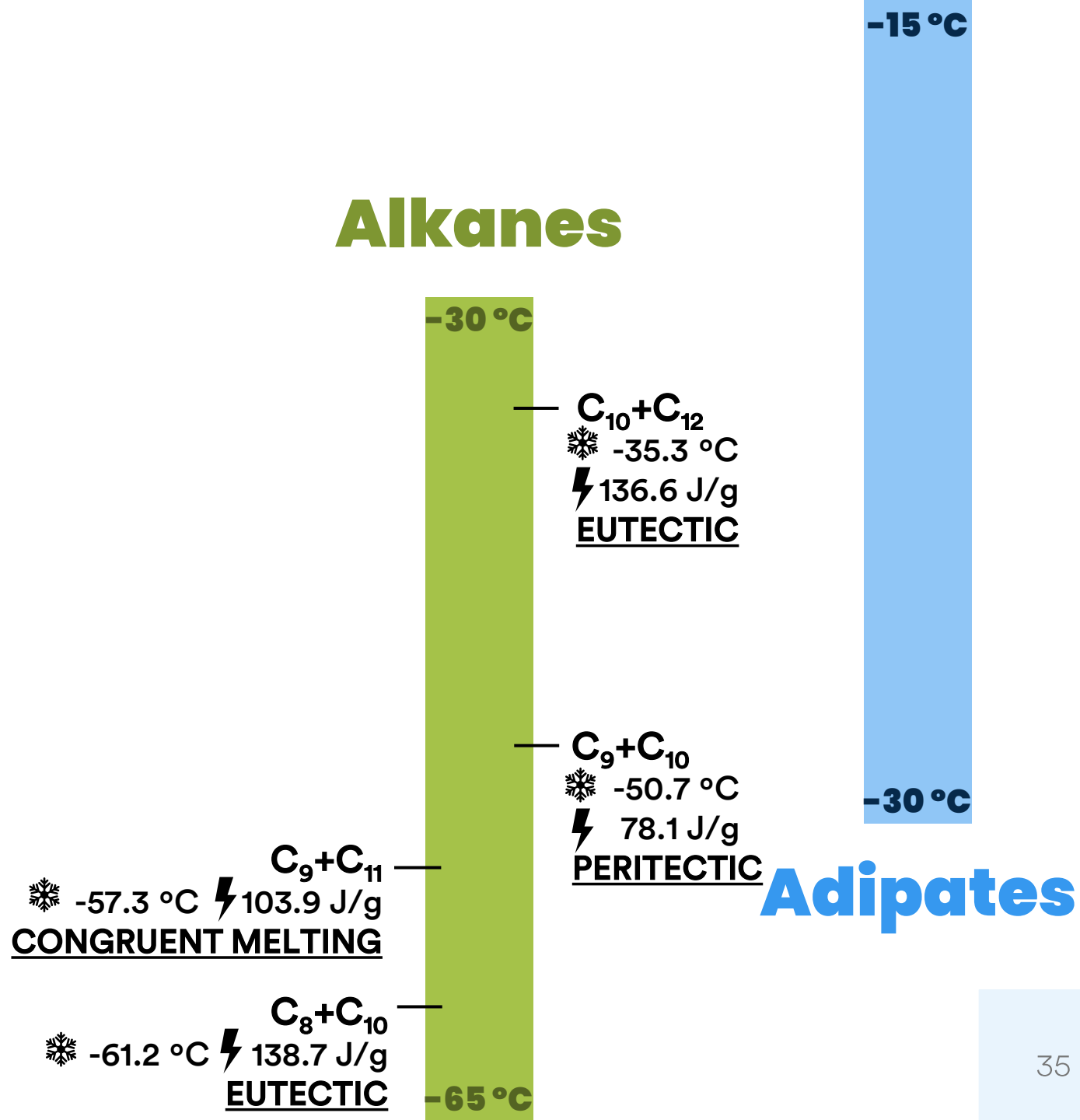


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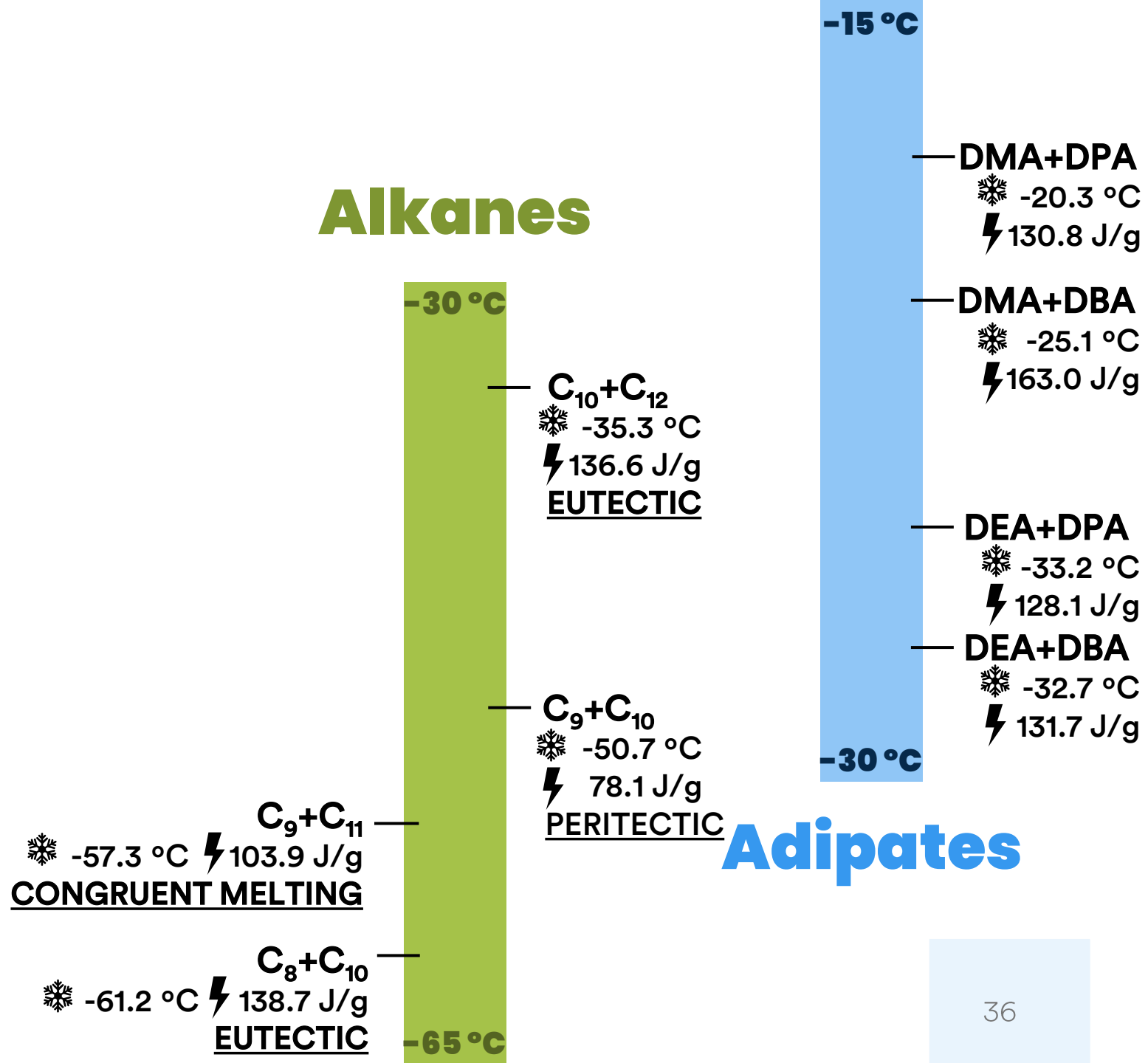
ENHANCING THERMAL ENERGY STORAGE



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CONCLUSIONS

- 1**
8 Different binary systems as PCM candidates
- 2**
Different melting temperatures, different applications
- 3**
Similar latent heat of fusion, similar energy storage density
- 4**
Fulfill the lack of available data on low temperature PCM systems

Aknowledgments

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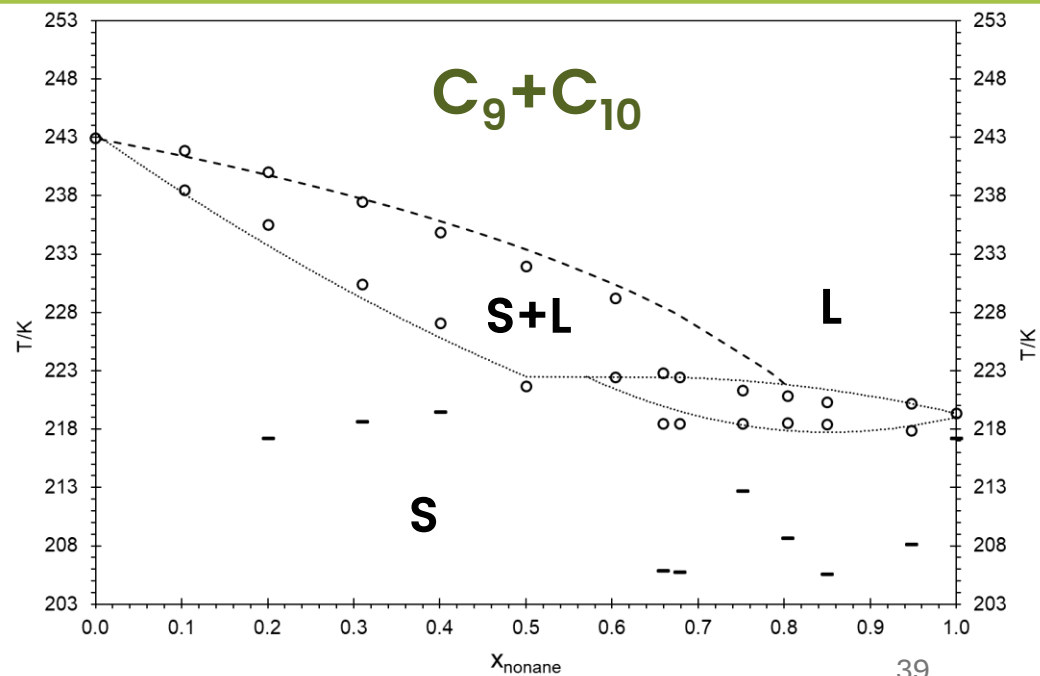
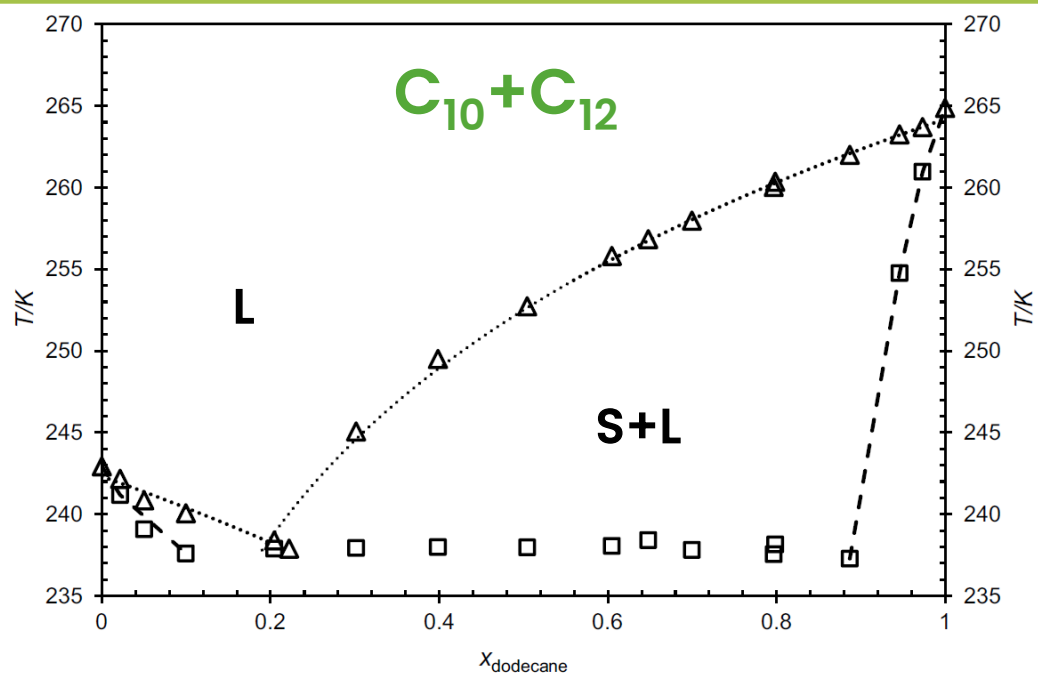
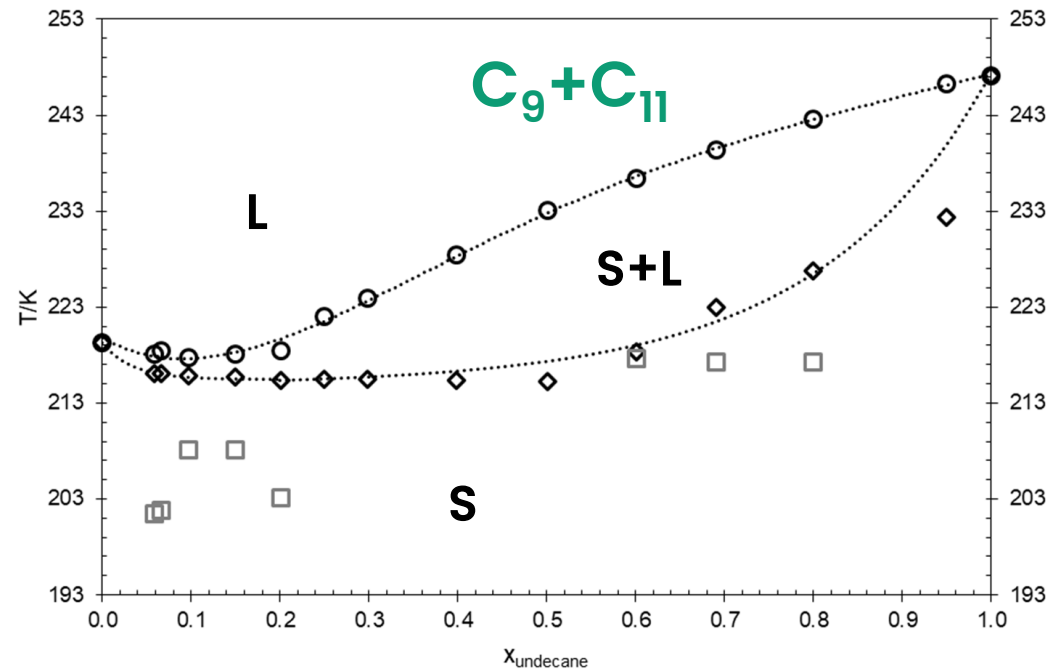
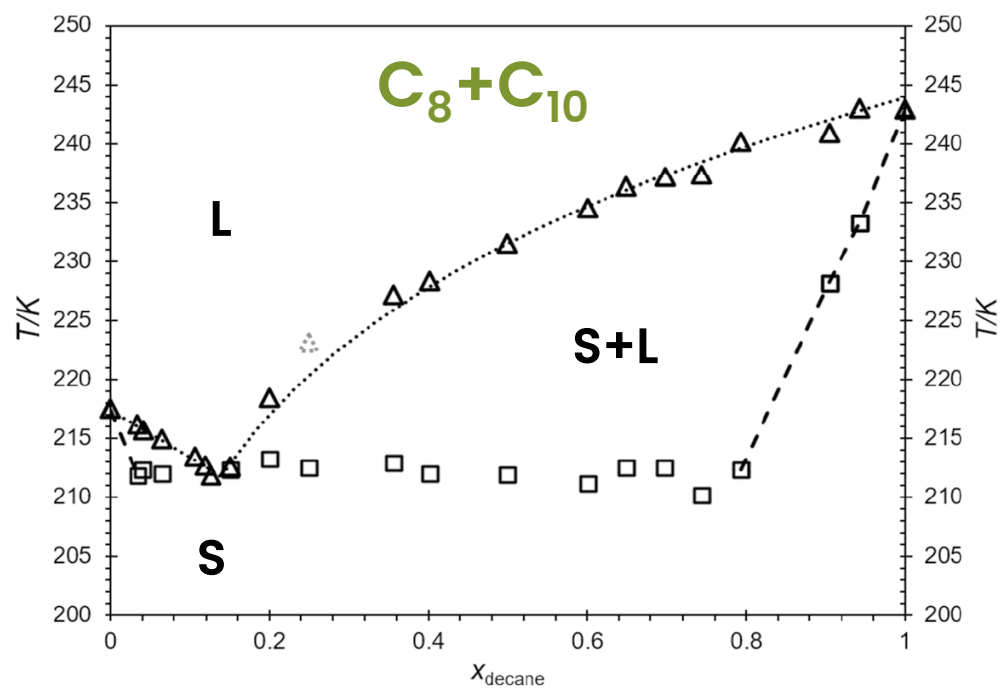


Fig. 1 Binary phase diagrams for the binary alkane systems C_8+C_{10} ; C_9+C_{11} ; $C_{10}+C_{12}$; C_9+C_{10} . Published in the International Journal of Thermophysics (IJT).

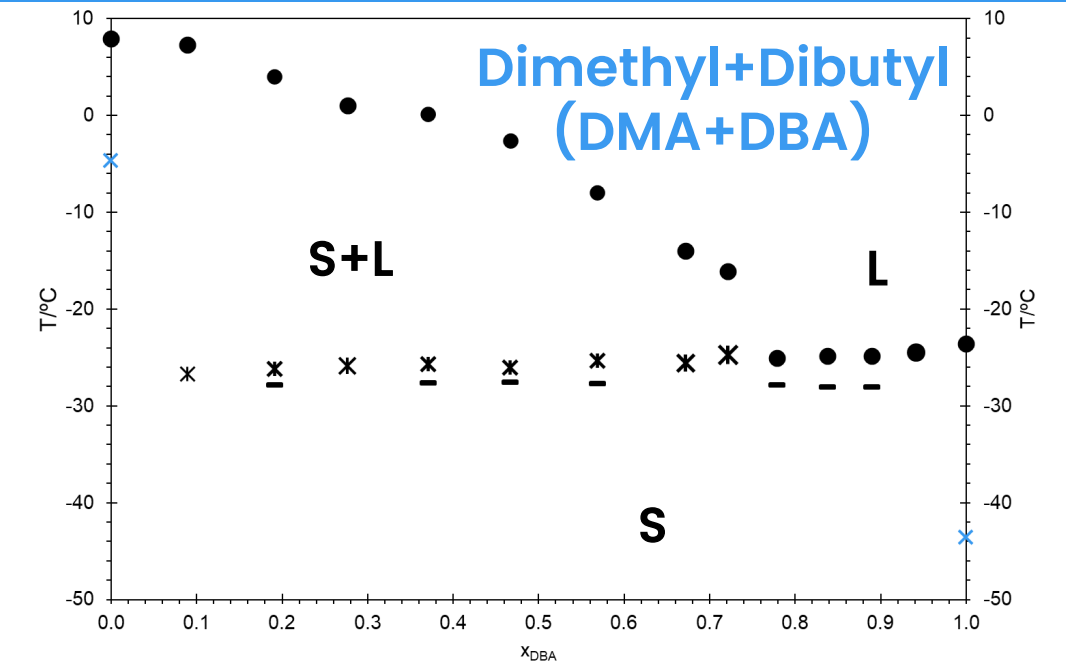
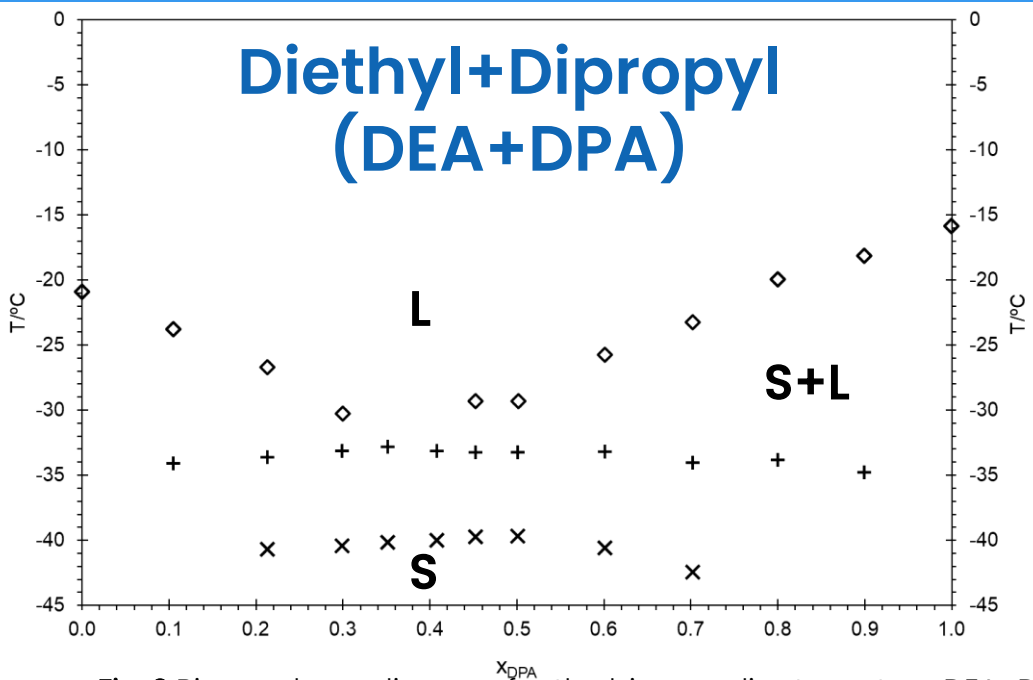
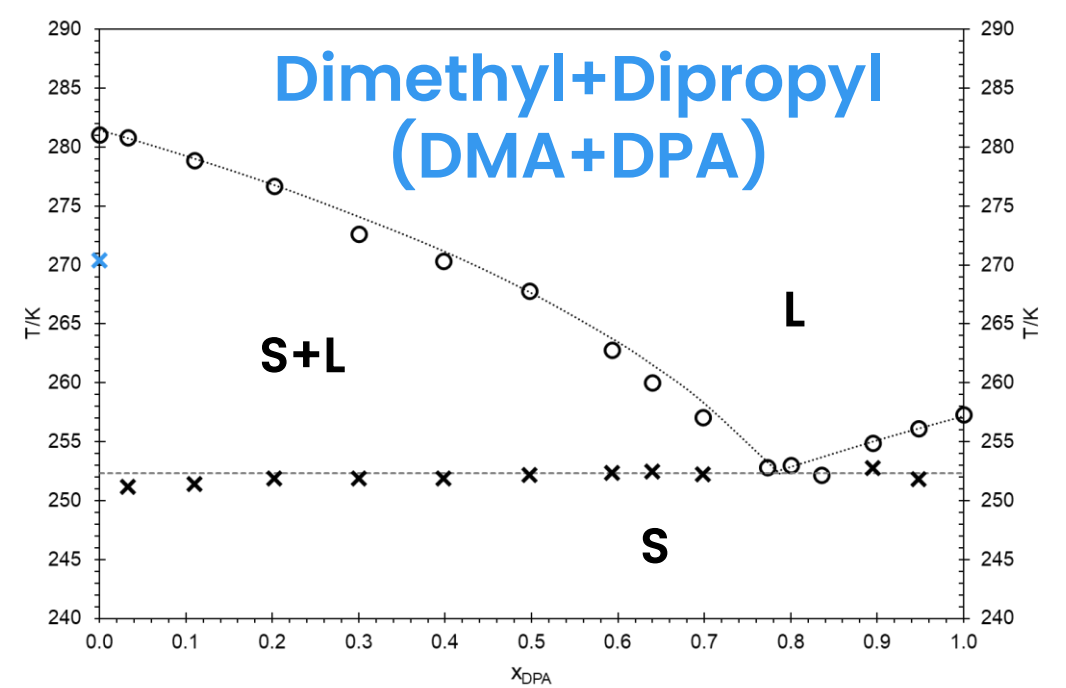
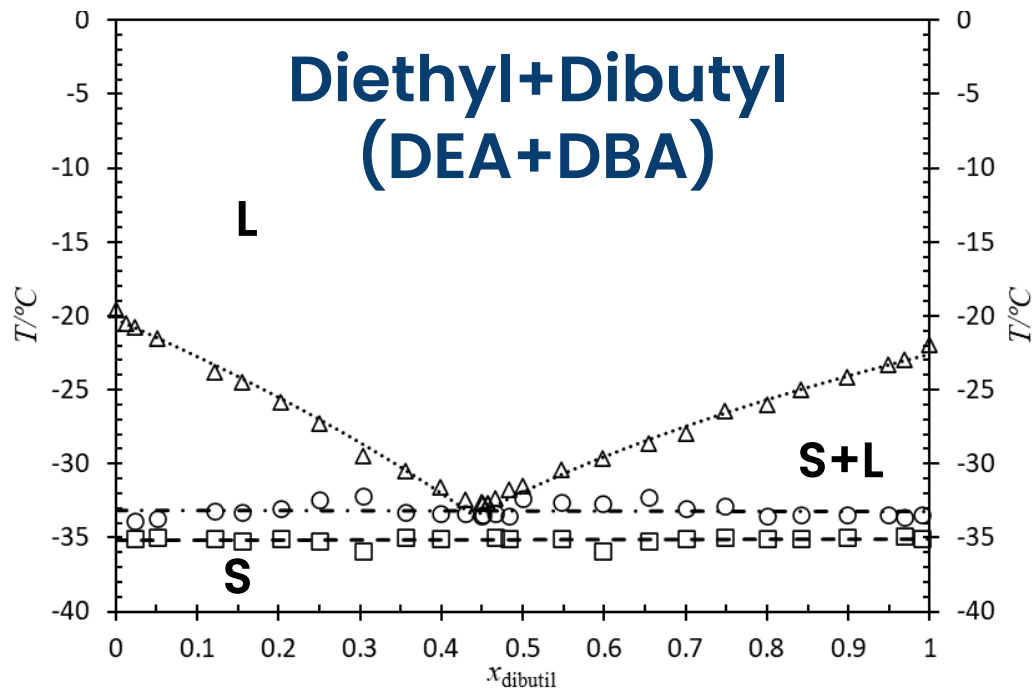


Fig. 2 Binary phase diagram for the binary adipate system DEA+DBA (Published in the IJT); and preliminary ones for DMA+DPA; DEA+DPA; DMA+DBA.