Thermal Properties and Thermal Stability of Binary Na_2CO_3-K_2CO_3 System for High-Temperature Thermal Energy Storage

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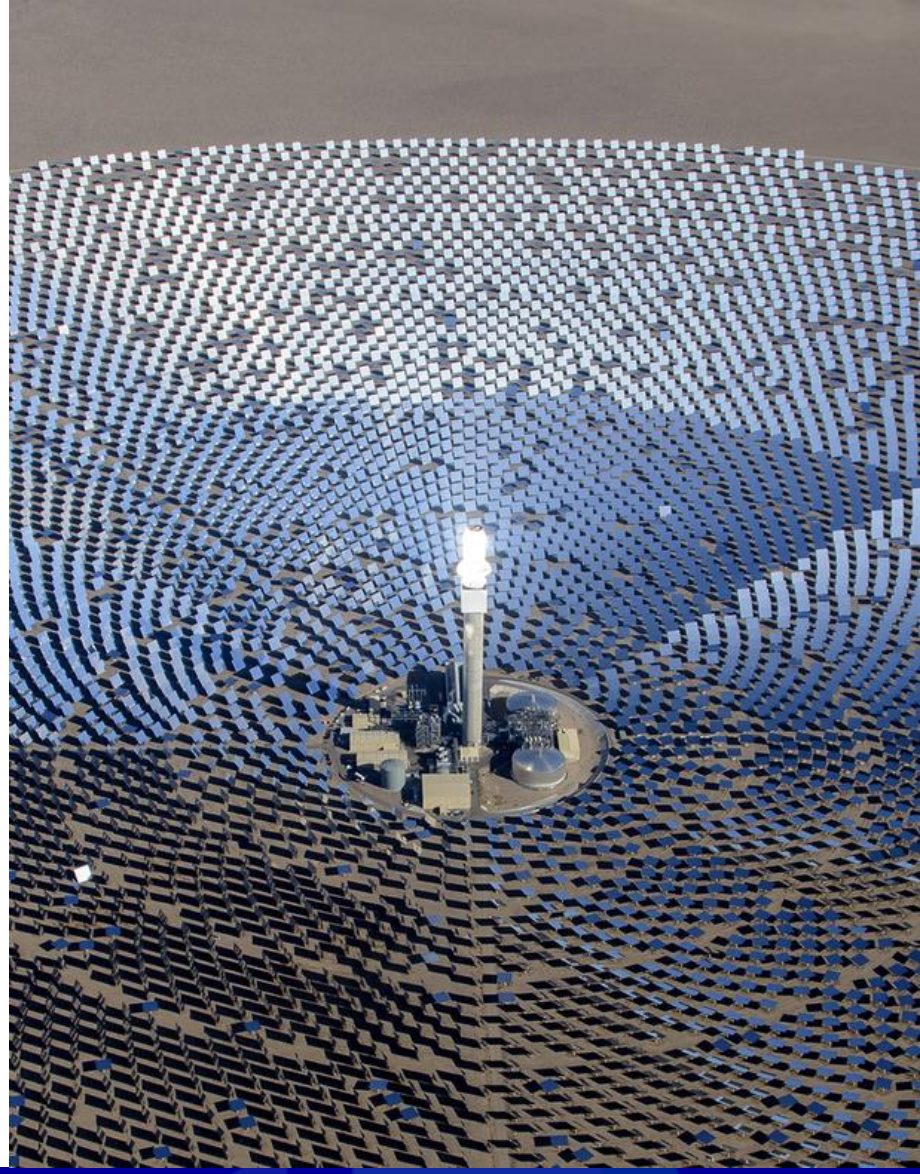
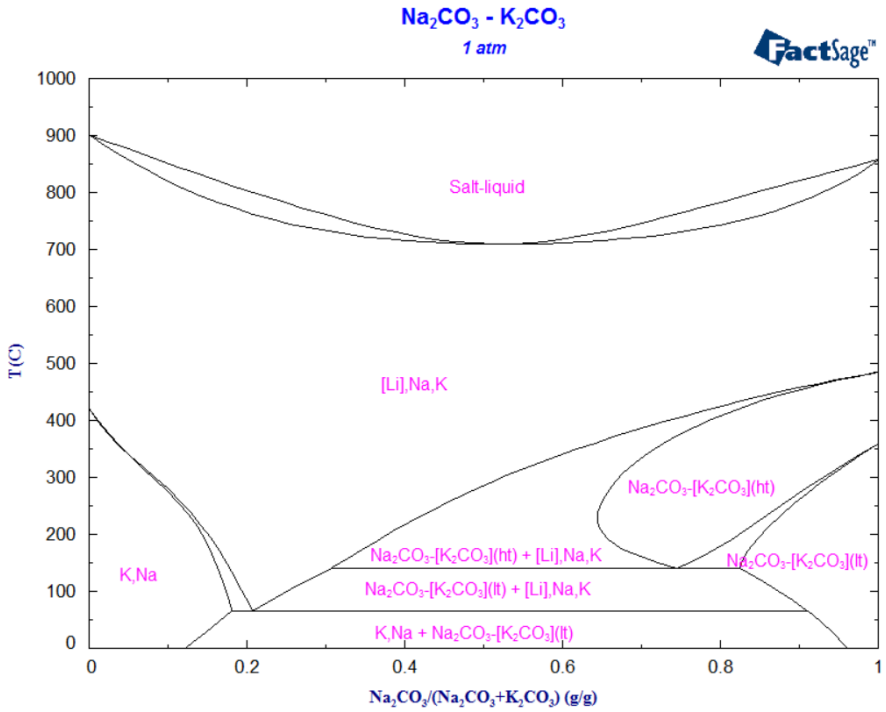
Background

- Modern CSP systems are aiming for higher temperatures (> 700°C) to increase turbine efficiency and reduce costs
- The current storage material (sodium/potassium nitrate) has a maximum operating temperature of 600°C, therefore a new material is required
- Latent heat storage using phase change materials (PCMs) has been considered as low-cost, energy dense storage media



Material Selection and Research Aim



- **To achieve a turbine inlet temperature >700°C, storage is required at ≈ 710-720°C**
- **Eutectic Na_2CO_3-K_2CO_3 is of particular interest to enable energy storage at above 700°C**

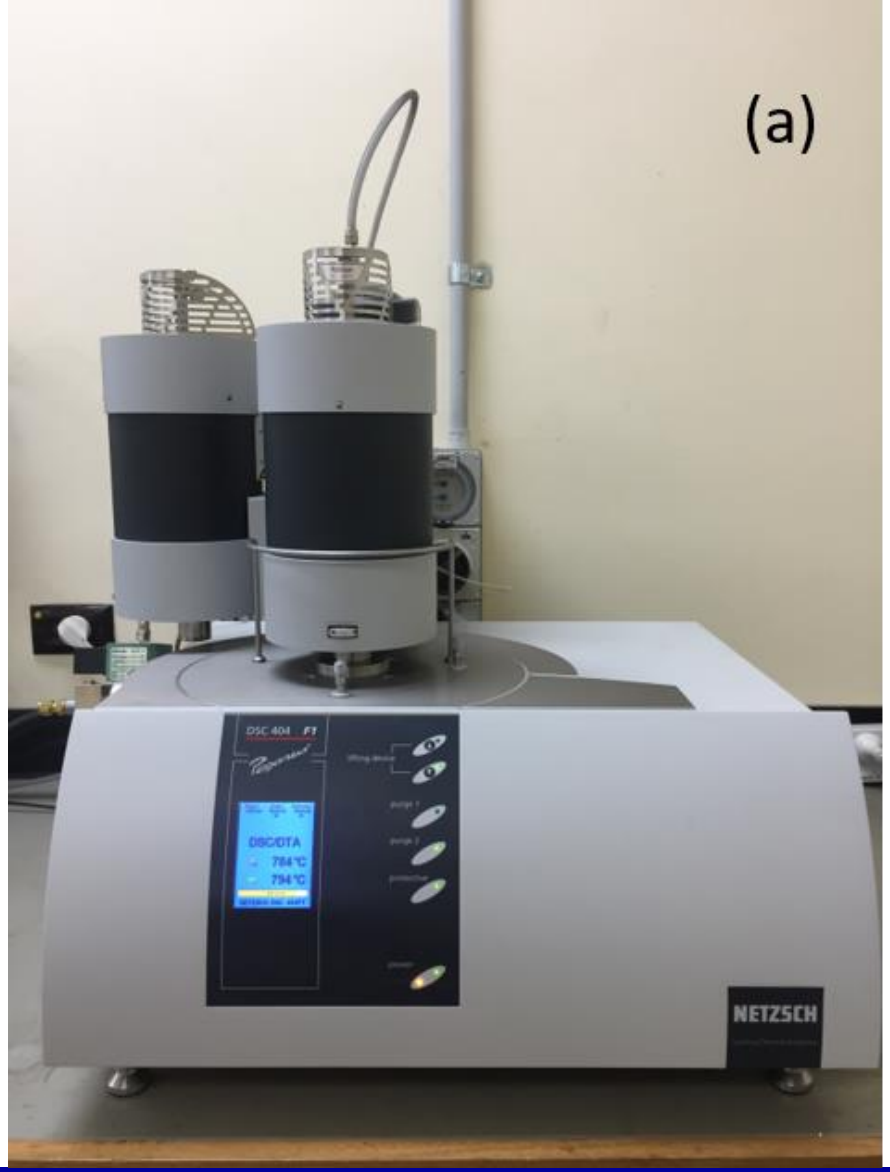
Research Aim

- **To achieve maximum enthalpy, this work studied the thermophysical properties of Na_2CO_3-K_2CO_3 system at different ratios**
    - *In particular the melting/freezing point and latent heat were investigated*
- **The thermal stability was also investigated**

Methodology

- **Varying compositions and liquidus temperatures were predicted**
- **Samples made by drying, weighing, and combining components before an initial melt**

Sample Number	Na_2CO_3 (mol%)	K_2CO_3 (mol%)	Predicted Liquidus Temperature (°C)
1	45	55	733
2	55	45	710
3	60	40	710
4	65	35	717
5	75	25	747



Methodology

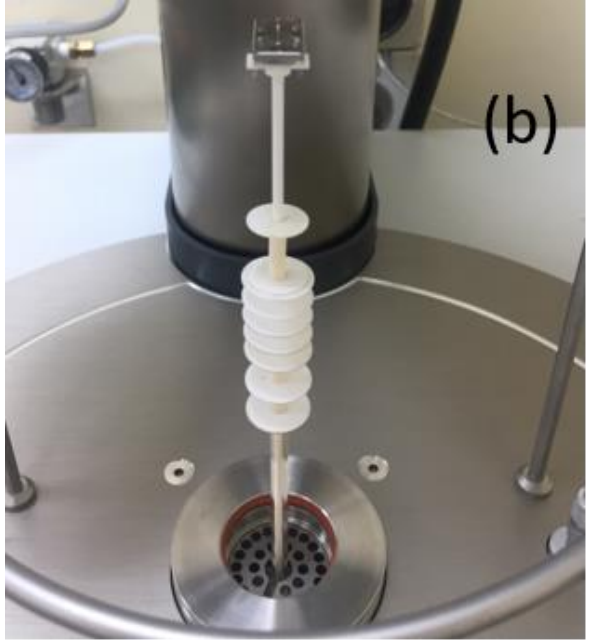
Differential scanning calorimetry (DSC)

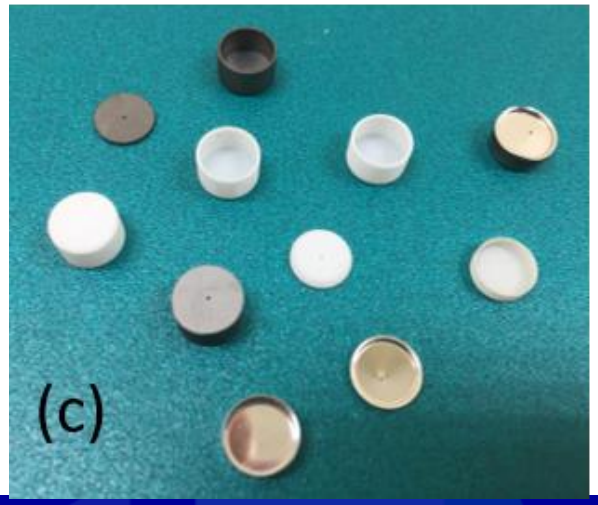
- To measure phase change temperature and enthalpy
- Graphite crucible, N_2 flow of 20 ml/min
- Two heating and cooling thermal cycles between 650°C and 50°C above predicted liquidus temperatures
- Heating/cooling rate of 10°C/min

Methodology

Simultaneous Thermal Analysis (STA)

- To evaluate the thermal stability up to 800°C.
- Heating rate of 20°C/min.
- Pt/Rh crucible, N_2 flow of 50 ml/min.



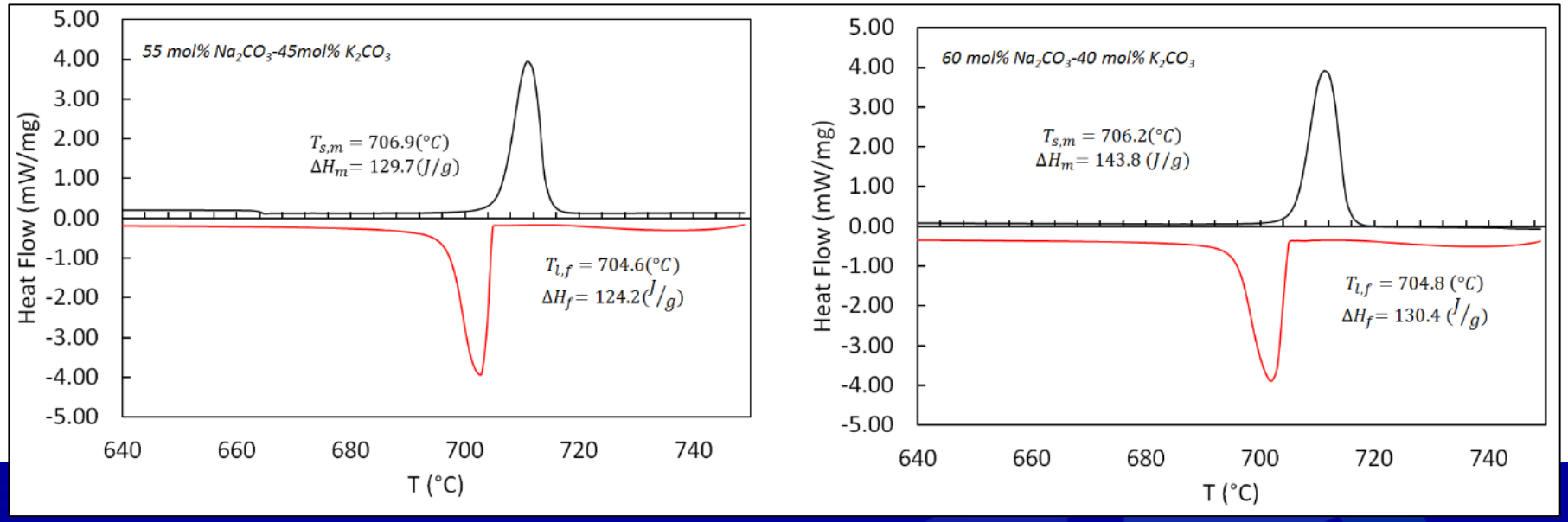


Results

Phase Change Temperature and Enthalpy

Eutectic compositions: 55 mol% and 60 mol% Na_2CO_3- K_2CO_3

- Sharp single peak
- Minimal difference in liquidous and solidus temperatures indicates minimal subcooling

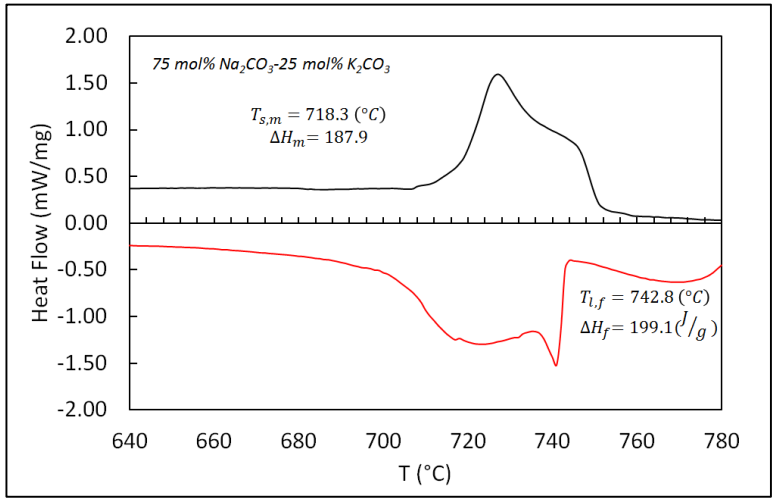


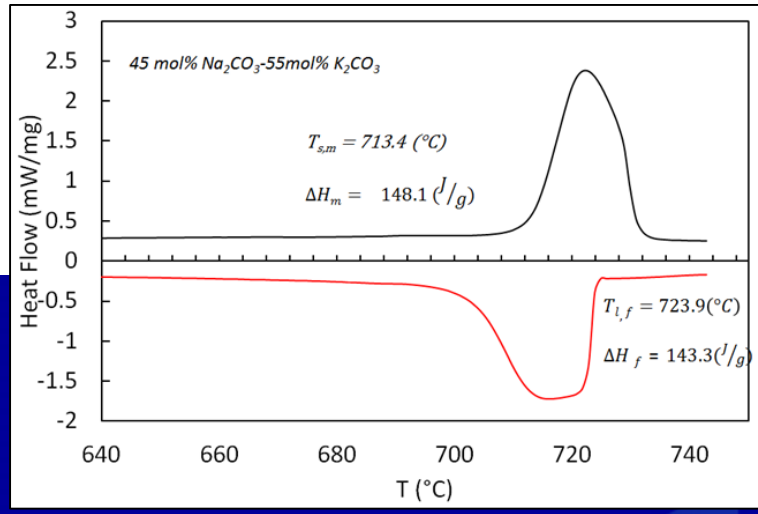
Results

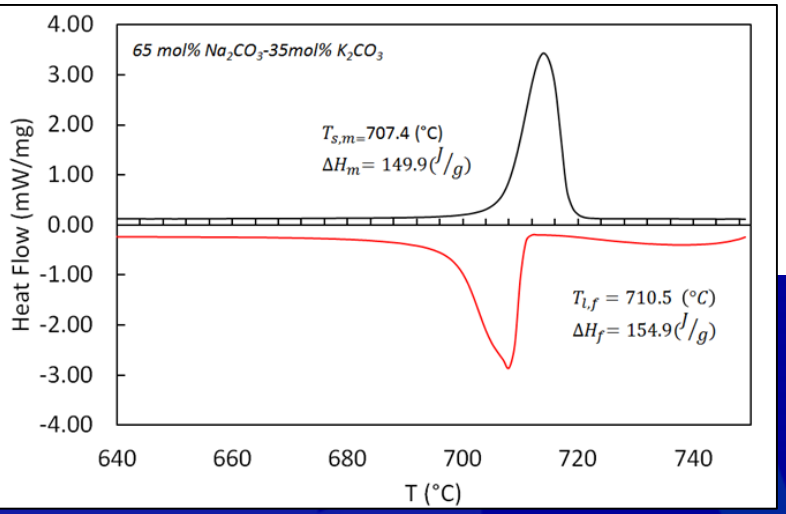
Phase Change Temperature and Enthalpy

Non-eutectic compositions: 45 mol%, 65 mol%, and 75 Na_2CO_3- K_2CO_3

- Wider peak curves in both melting and freezing
- Higher enthalpy of fusion compared to eutectic compositions.

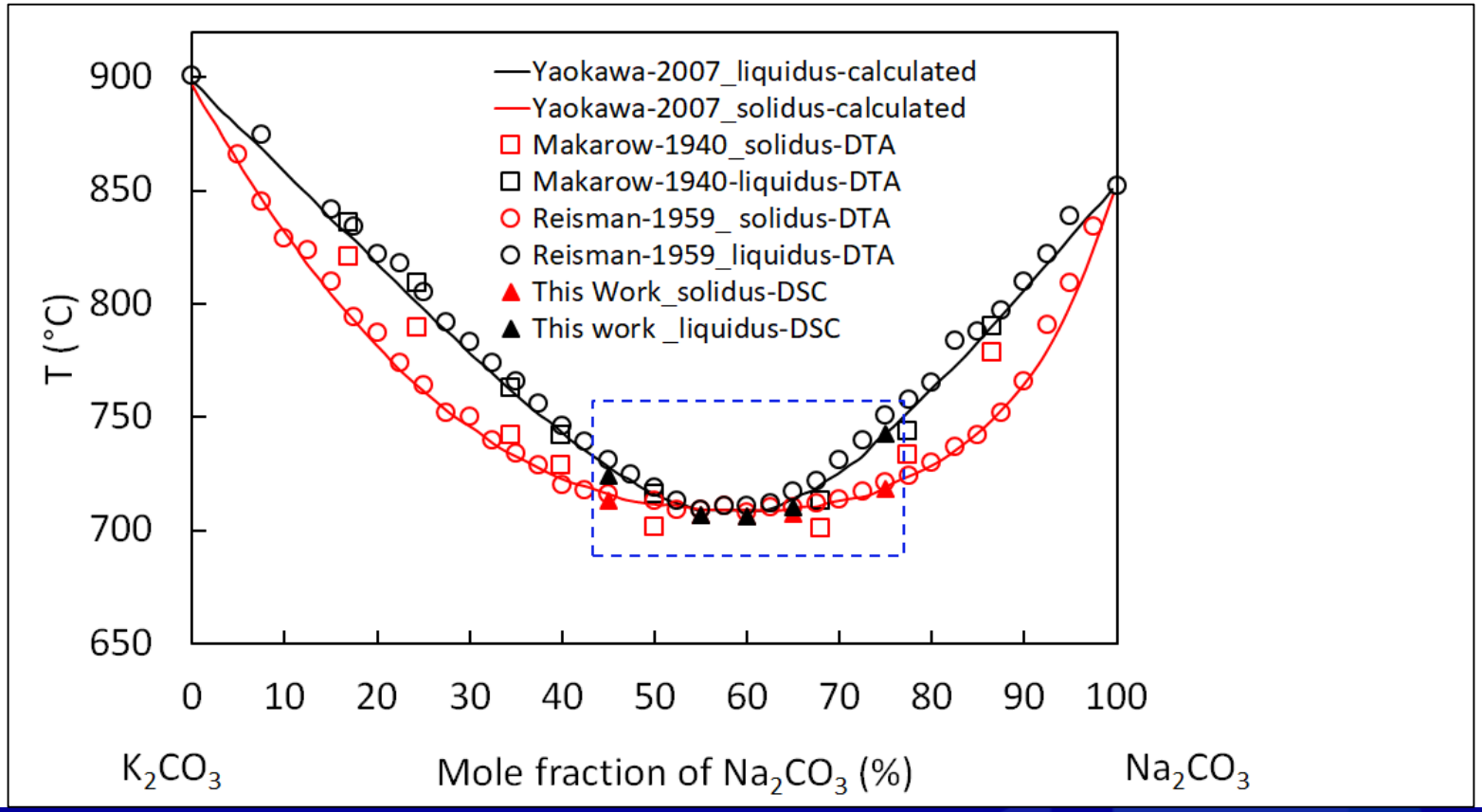






Results

Comparison with Published Results



Summary of Results

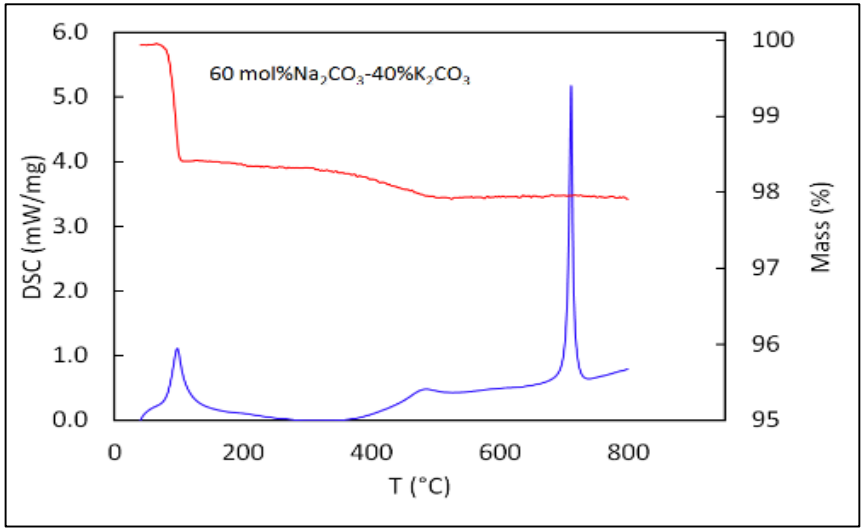
A summary of the measured transition temperature and latent heat for different compositions of the Na_2CO_3-K_2CO_3 system

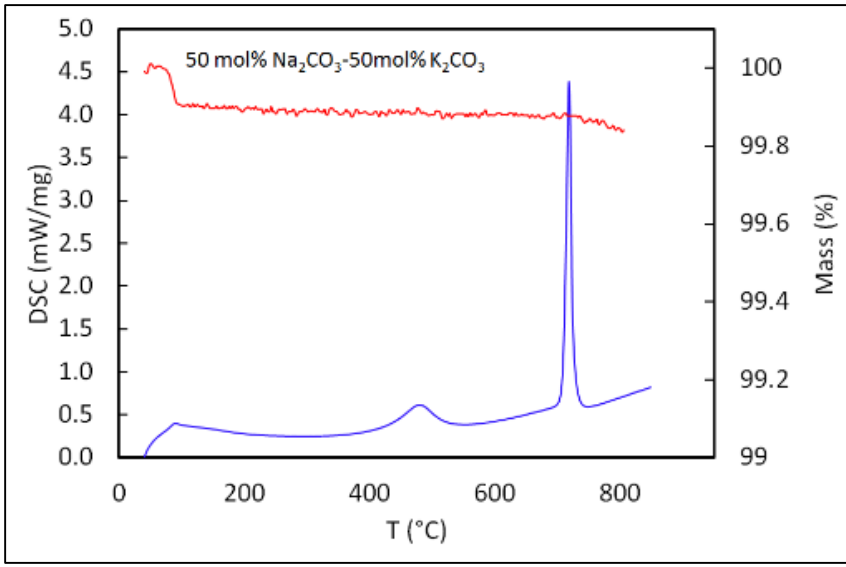
Property	Composition (mol% of Na_2CO_3)				
	45	**55**	**60**	**65**	**75**
$T_{s,m}$ (°C)	713.4	706.9	706.2	707.4	718.3
$T_{l,m}$-$T_{s,m}$ (°C)	10.5	0.0	0.0	3.1	24.5
ΔH_m (J/g)	148.1	129.7	143.8	149.9	187.9

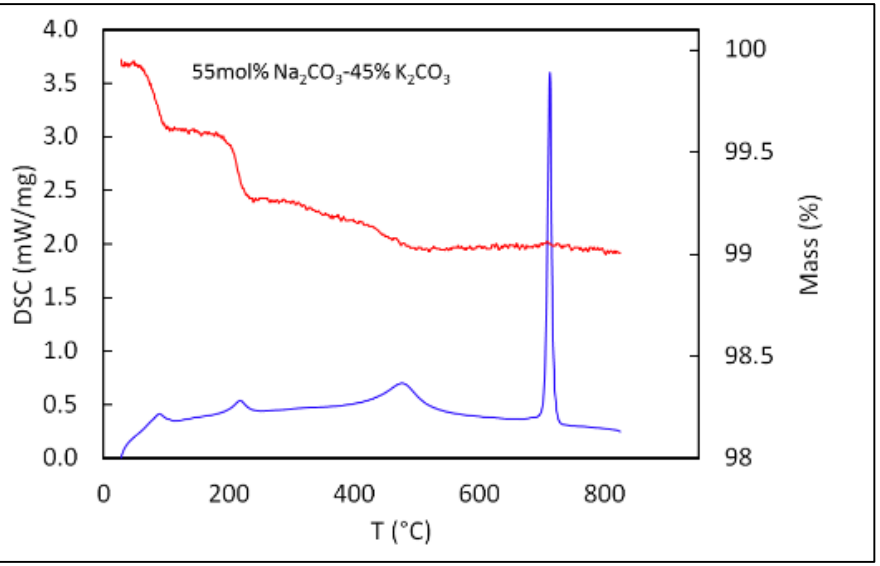
Results

Thermal Stability

STA analysis of 50,55 and 60 mol% Na_2CO_3 up to 800°C







Conclusions

- Thermophysical properties of Na_2CO_3-K_2CO_3 system at different compositions of 45, 55, 60, 65 and 75 mol% Na_2CO_3 were assessed
- Measured transition temperatures are in good agreement with the published results
- Compositions of 55 and 60 mol% Na_2CO_3 were identified as the eutectic points with minimum temperatures of 706.9 and 706.2°C
- 60 mol% Na_2CO_3 sample offers a higher enthalpy of fusion
- Although the phase change of non-eutectic compositions is not isothermal, they offer higher enthalpy of fusion and could be potential high-temperature energy storage materials
- 55 and 60 mol% Na_2CO_3 samples are thermally stable from 480°C to 800°C

Thankyou

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