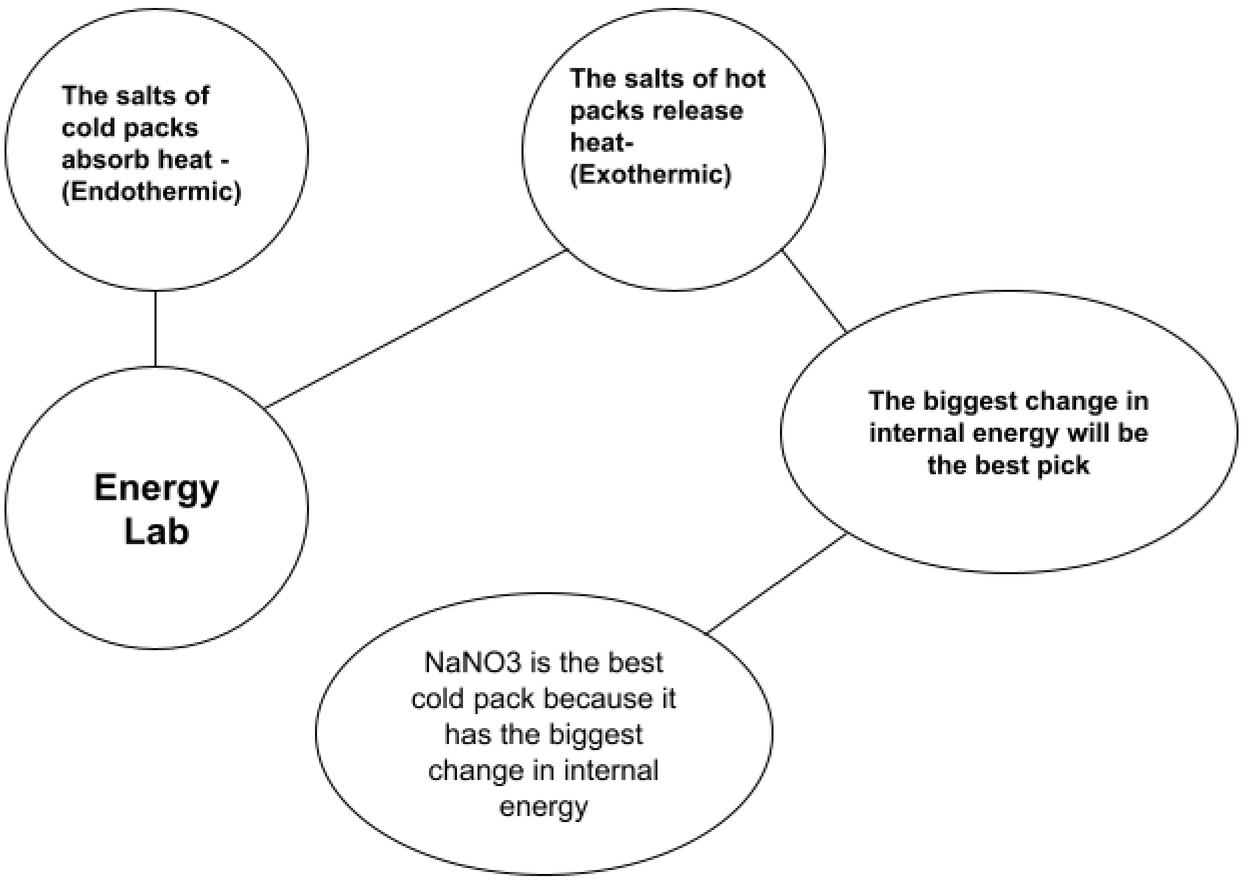
Course: CHM 151AA

Before you begin, Go to File → **Make a Copy** and Save in your personal Google Drive

Brainstorm what you experienced in the lab to select a Main Claim:

Bubble Map

Double click on the map below and fill in experiences/observations from the lab



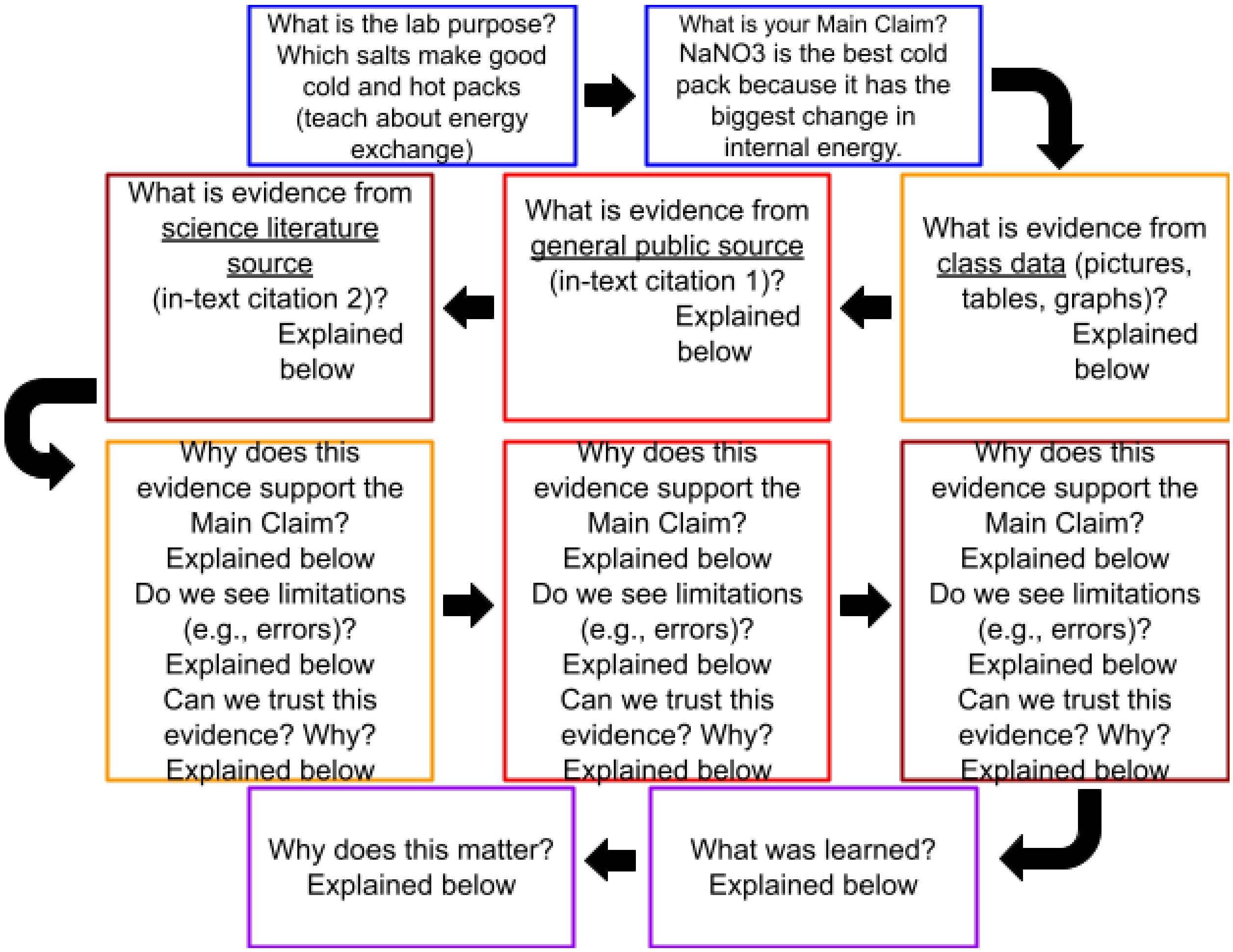
Pick one bubble to focus on for this lab write-up

Main Claim: $NaNO_3$ is the best cold pack because it has the biggest change in internal energy.

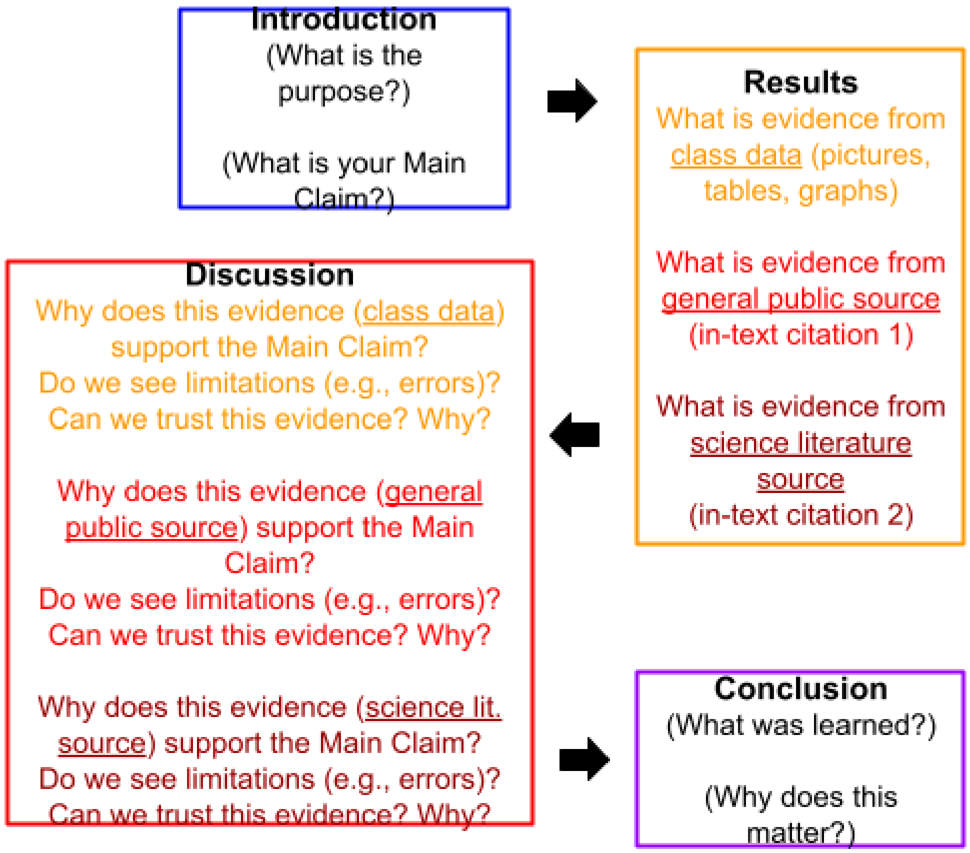
Develop an outline for your Lab Write-up:

Flow Map Outline

Double click on the map below and fill in briefly based on your lab experience



Lab Write-Up Format
(for reference ONLY)



Lab Write-Up
***Copy* your outline information above and then <u>elaborate</u> in sentence-form**

Introduction

Purpose: Which salts make good cold and hot packs (teach about energy exchange). This was done by placing varying amounts of different salts in water and recording their temperatures.

My Claim: $NaNO_3$ is the best cold pack because it has the biggest change in internal energy.

Results

Class Data:

1	-			Group 4: Team 2		
2	Data Collection		**Team 2**	Temperature Change	Reaction Type	Sign of q
3	Key		Salt	(Increase, Decrease, or Neither)	(endothermic, exothermic, or isothermic)	(+, -, or 0)
4	**More intense change**		CaCl2	neither	isothermic	0
5	Less intense change		MgCl2	increase	exothermic	-
6			Mg(NO3)2	decrease	endothermic	(+)
7		Potential Salts	KCl	decrease	endothermic	(+)
8			NaNO3	decrease	endothermic	(+)

Image (1)

20			Group 3					
21	**Part 2**		Best for Iso? Pack #2: KNO3			Best for Cold Pack #2: NaNO3		
22	Data Collection		Trial 1: 4g	Trial 2: 6g	Trial 3: 8g	Trial 1: 4g	Trial 2: 6g	Trial 3: 8g
23	Mass of salt	(g)	4.005	5.949	8.037	4.003	6.002	8.002
24	**Average Mass**	**Ave g**			5.997			6.002
25	Temperature Change (ΔT)	(Final - Initial)	-3	-4	-5	-2	-3	-3
26	**Average Temperature Change**	**Ave ΔT**			-4			-2.667
27	Temperature Change given Mass	ΔT/g	-0.749	-0.672	-0.622	-0.500	-0.500	-0.375
28	Average Temp Change given Mass	Ave			-0.681			-0.458
29								
30	Calculations							
31	**Heat exchanged (q)**	**(J)**			-100.366			-66.975
32	Heat exchanged	(kJ)			-0.100366			-0.066975
33	Moles of salt	(mol)			0.059			0.071
34	Change in Internal Energy (Enthalpy: ΔH)	(kJ/mol)			-1.701			-0.943

20			Group 4					
21	**Part 2**		Best for Iso? Pack #2: KNO3			Best for Cold Pack #2: NaNO3		
22	Data Collection		Trial 1: 4g	Trial 2: 6g	Trial 3: 8g	Trial 1: 4g	Trial 2: 6g	Trial 3: 8g
23	Mass of salt	(g)	4.010g	6.001g	8.000g	3.899g	5.887g	8.058g
24	**Average Mass**	**Ave g**			12.6776667g			12.472g
25	Temperature Change (ΔT)	(Final - Initial)	-0.3	-0.5	-6.1	-1.3	-2.7	-4.7
26	**Average Temperature Change**	**Ave ΔT**			-0.47			-2.9
27	Temperature Change given Mass	ΔT/g	-0.075	-0.083	-0.763	-0.333	-0.459	-0.36
28	Average Temp Change given Mass	Ave			-0.307			-1.761
29								
30	Calculations							
31	**Heat exchanged (q)**	**(J)**			-24.931			-151.33
32	Heat exchanged	(kJ)			-0.024931			-0.15133
33	Moles of salt	(mol)			0.125			0.147
34	Change in Internal Energy (Enthalpy: ΔH)	(kJ/mol)			-0.199			-1.029

Image (2)

36	Class Interpretation from Part 2	Salt	Justification (QUANTitative)
37	**Ranked #1** for Hot Pack	MgCl2	positive Enthalpy
38			
39	**Ranked #1** Cold Pack	NaNO3	average approximately 1.0 kJ/mol, precise
40	Ranked #2 Cold Pack	NH4NH3	average 0.6 kJ/mol
41	Ranked #3 Cold Pack	KCl	average approximately 0.5 kJ/mol, precise
42	Ranked #4 Cold Pack	NH4Cl	higher variability, 0.8 and 0.3 kJ/mol
43	Best for Iso? Pack #2	KNO3	little precision, but exothermic water (endothermic salt)

Image (3)

I would like to point out that my group was group four. In image 2, I have included group three because we used their change in internal energy to get the average (rounded to the first decimal place).

The data from the table above (image 1) tells us that NaNO3's sign of "q" is positive (+), meaning that heat is absorbed, gaining energy, by NaNO3 from its surroundings. This is an endothermic process where NaNO3 is gaining energy. A negative sign of “q” would indicate heat is being released from a system to its surroundings, which occurs during an endothermic process where a system loses energy.

In images 2 and 3, we see that NaNO3 had the highest change in internal energy during dissolution, which is the determining factor in our experiment for deciding which cold pack would be the most effective in absorbing heat, creating the strongest cooling effect.

Public Source: Instant Cold Packs
The procedure for using an instant chemical cold pack involves shaking the contents to mix water (solvent) with ammonium nitrate, calcium ammonium nitrate, or urea (solute(s)), which are chemicals with a negative heat of dissolution. Upon activation, these compounds dissolve in water, absorbing heat from their surroundings and causing a cooling effect. This endothermic reaction produces temperatures between 20F to 40F, lasting for at least 15 minutes. The dissolution process occurs in three steps, breaking solute-solute attractions, breaking interactions between water molecules, and forming solvent-solute attractions, the last step being exothermic. However, because the energy absorbed during the first two steps is greater than the energy released, the result we feel when holding a cold pack is a cooling sensation (*Instant Cold Packs*, n.d.).

Science Literature Source: Experimental Studies on Endothermic Reversible Reaction of Salts for Cooling

Table 2. Various salt mixtures and maximum temperature drop.

Code	Salt mixture composition	Maximum temperature drop °C
NPK1	80g NH_4NO_3 + 20g NH_4Cl	30.1
NPK2	50g NH_4NO_3 + 20g NH_4Cl + 20g $(NH_4)_2CO$ + 5g KNO_3 + 5g $(NH_4)H_2PO_4$	30.1
NPK3	60g NH_4NO_3 + 15g NH_4Cl + 15g $(NH_4)_2CO$ + 5g KNO_3 + 5g $(NH_4)H_2PO_4$	29.9
NPK4	70g NH_4NO_3 + 10g NH_4Cl + 10g $(NH_4)_2CO$ + 5g KNO_3 + 5g $(NH_4)H_2PO_4$	30.4
NPK5	NH_4NO_3 + 5g NH_4Cl + 5g $(NH_4)_2CO$ + 5g KNO_3 + 5g $(NH_4)H_2PO_4$	28.8
NPK6	50g NH_4NO_3 + 40g $(NH_4)_2CO$ + 5g KNO_3 + 5g $(NH_4)H_2PO_4$	31.9
NPK7	50g NH_4NO_3 + 25g $(NH_4)_2CO$ + 20g K_2SO_4 + 5g $(NH_4)H_2PO_4$	28.7
NPK8	50g NH_4NO_3 + 30g K_2SO_4 + 15g $NaNO_3$+ 5g $(NH_4)H_2PO_4$	16.7
NPK9	50g NH_4NO_3 + 40g $NaNO_3$ + 10g $(NH_4)H_2PO_4$	26.6
NPK10	70g NH_4NO_3 + 20g $NaNO_3$ + 10g $(NH_4)H_2PO_4$	27.4
NPK11	50g NH_4NO_3 + 25g $NaNO_3$ +20g KNO_3 + 5g $(NH_4)H_2PO_4$	29.3
NPK12	50g $(NH_4)_2CO$ + 30g NH_4Cl + 20g K_2SO_4	26.2
NPK13	40g NH_4Cl + 25g $(NH_4)_2CO$ + 30g KNO_3 + 5g $(NH_4)H_2PO_4$	25
NPK14	50g NH_4Cl + 20g $(NH_4)_2CO$ + 30g KNO_3	25.4

Image (1)

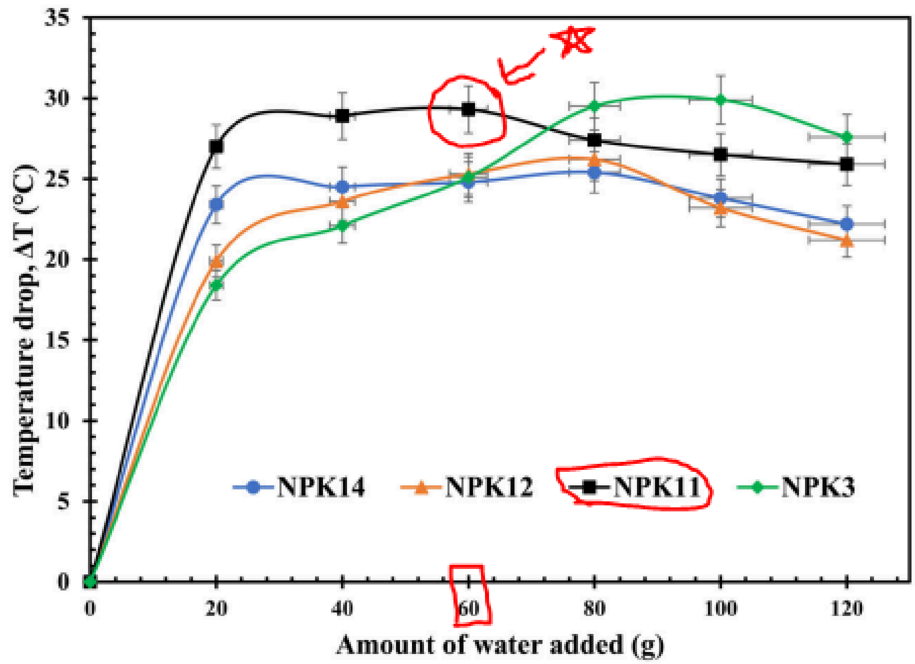


Figure 3. Temperature drop after adding water to salt mixtures: NPK14, NPK12, NPK11 and NPK3.

Image (2)

This study investigated the cooling effects of fertilizer-based salts (using specific mixtures of (NPK) nitrogen, phosphorus, and potassium-based salts), exploring their potential as environmentally friendly, cost-effective materials for thermochemical energy storage and cooling applications. The study reports significant temperature drops for various salts when mixed with water, with NaNO3 as a member of group NPK-11 (50g NH4NO3 + 25g NaNO3 + 20g KNO3 + 5g (NH4)H2PO) showing one of the highest temperature reductions, 29.3C in the study (image 1). It is worth noting that while NPK-11 did not have the highest temperature reduction, it did have the highest reduction when 60 grams of water was added (image 2), which is advantageous since "...a lower amount of water is preferred because the water in the salt must be evaporated in order to use the salts again" (Desai et al., 2021). The study explains that the cooling effect is primarily caused by the dissolution of salts such as NaNO3, which absorb heat from the surroundings (endothermic process) as they dissolve in water.

Discussion

Class Data:

The class data supports the main claim because our experiments/data and another group's experiments/data illustrated that $NaNO_3$ is endothermic, causes the greatest temperature drop, and has the highest average change in internal energy expressed in kJ/mol. This significant endothermic reaction makes it the best choice for cold packs.

There are limitations such as human error in the measurement accuracy like measuring the mass of the salt and differences in reading the temperature. Another variable could be heat loss to the outside environment despite our use of styrofoam cups.

Ultimately we can trust this evidence because of the repetition of the experiment with different amounts of salt, the insulation of the styrofoam cups does help reduce heat loss, and the procedure is controlled by the step-by-step process that keeps the variables (volume of water, salt mass) are kept consistent as possible.

Public Source:

Many commercial cold packs use compounds like ammonium nitrate (NH_4NO_3) and sodium acetate because they undergo endothermic reactions that absorb heat, resulting in a cooling effect (Libretexts, 2021). For instance, the dissolution of ammonium nitrate in water absorbs heat, lowering the temperature of the surrounding environment, which is the principle behind the cooling effect in instant cold packs (*Instant Cold Packs*, n.d.). Sodium nitrate ($NaNO_3$) we tested in class, a similar compound, behaves in the same way by pulling thermal energy from its surroundings during dissolution. This suggests that $NaNO_3$'s ability to absorb heat could make it a good choice for cold packs.

The limitations from this source could be heat loss to surroundings based on cold packs varying insulation properties, the different chemical dissolution features from the different chemicals mentioned (ammonium nitrate, calcium ammonium nitrate, or urea) as well as variations in purity of the respective chemicals. Finally, since the cold packs rely on individuals squeezing an inner pouch to activate them, if the pouch isn't broken completely or not properly mixed, there is the possibility of incomplete cooling effects or delayed cooling.

Overall, the evidence can generally be trusted based on the consistency of the procedure, primarily the chemical principles behind the reactions, potential sources of error (heat loss, chemical variability) should be considered when looking at the results.

Despite the aforementioned limitations, the experiment provides a worthy outside example of endothermic reactions that drive the cooling effect.

Science Literature Source:
The study explains that the cooling effect is primarily caused by the dissolution of salts such as NaNO3, which absorb heat from the surroundings as they dissolve in water. This matches our experiment, where NaNO3 exhibited the highest change in internal energy, indicating that it absorbs more heat than other salts, which leads to a more robust cooling effect. Additionally, the study showcased that the combination of nitrate-based salts like NaNO3 resulted in higher cooling effects compared to other salt mixtures, reinforcing the evidence that NaNO3 is an effective cold pack material due to its significant ability to absorb heat, making it ideal for applications like instant cooling packs, supporting my claim (Desai et al., 2021).

The study mentioned its own limitations that applied to commercial use, stating more research would be necessary to, "...investigate salt agglomeration, solubility, thermal stability and heat of evaporation which are still unknown" (Desai et al., 2021).

This study can be trusted because it is based on a systematic series of experiments testing on a variety of fertilizer-based salts, such as ammonium nitrate (NaNO3), and their cooling effects when dissolved in water. The study showcases quantitative data on the temperature drop achieved by these salts, including NaNO3, which supports its endothermic properties for the team's research goals.

Conclusion

In conclusion, from this lab, I learned that NaNO3 exhibited the highest change in internal energy among various salts tested, reflecting its strong endothermic properties and its rightful place as the most effective cold pack. The dissolution of NaNO3 in water absorbs heat from the surroundings, producing a cooling effect, which makes it suitable for instant cold packs. This conclusion is supported by data from both our lab and external studies, like the "Experimental Studies on Endothermic Reversible Reaction of Salts for Cooling," which shows that NaNO3 produces significant cooling power when dissolved. This matters because understanding the most effective salts for cold packs can lead on to better material choices for therapeutic cooling, industrial refrigeration, and energy-efficient cooling solutions. By using salts like NaNO3, we can improve the performance and sustainability of cooling systems.

References

Desai, F., Atayo, A., Prasad, J. S., Muthukumar, P., Rahman, M., & Asmatulu, E. (2021). *Experimental Studies on Endothermic Reversible Reaction of Salts for Cooling*. Heat Transfer Engineering, 42(13/14), 1107–1116. https://doi-org.libproxy.estrellamountain.edu/10.1080/01457632.2020.1777002

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