Design Study of Saving Solar Energy by Sodium Chloride or Sodium Bicarbonate Solution

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Abstract

An experimental investigation for the solar energy saving by using pure sodium chloride or sodium bicarbonate salts which are added individually to 250 gm of distilled water(in conical flask) with different adding's (concentrations),during 45 minutes for losing the heat gained from the sun ,then we calculate the decreasing in temperature after the sun set. For the adding of 7.4gm (2.96 wt.%) of each NaCl or NaHCO3,from which we saw that the temperature is decreases from 50 to 42 C^o during 45 minutes for NaCl solution, while from 49 to 42.2 C^o for NaHCO3 solution. Also the same behavior for 5.9 wt. %. While for (8.88-26.64 wt. %) the temperatures are decrease with time, but we saw the curves of NaCl solution in all these figures has the greater value than the curves of NaHCO3 solution. The heat capacity of the two salts is increasing with increasing their weight percent, and the heat capacities of NaHCO3 solution are greater than the heat capacities for NaCl solution.

Keywords: Solar Energy, Saving Energy, Sodium Salts, Molten Salts, Heat Capacity.

Introduction

Thermal energy storage comprises a number of technologies that store thermal energy in energy storage reservoirs for later use. They can be employed to balance energy demand between day time and night time. The thermal reservoir may be maintained at a temperature above (hotter) or below (colder) that of the ambient environment. The applications today include the production of ice, chilled water, or eutectic solution at night, or hot water which is then used to cool / heat environments during the day or for electricity production.

Thermal energy is often accumulated from active solar collector or more often combined heat and power plants, and transferred to insulated repositories for use later in various applications, such as space heating, domestic or process water heating. Most practical active solar heating systems have storage for a few hours to a day's worth of energy collected. There are also a small but growing number of seasonal thermal stores, used to store summer energy for space heating during winter. Molten salt is now in use as a means to retain a high temperature thermal store, in conjunction with concentrated solar power for later use in electricity generation, to allow solar power to provide electricity on a continuous basis, as base load energy [Mancini, 2006].

Phase change material (PCMs) are divided into two main families: organic and inorganic. Organic materials can be further classified into paraffin and non-paraffin such as esters, fatty acids, alcohols and glycols. Inorganic materials are subdivided into salt hydrates and metallic. Mixtures of chemical compounds constitute practical PCM and this leads to a Melting/solidification temperature range as compared to using pure chemicals. Eutectic mixtures of organic and/or inorganic materials are desirable in that they melt/solidify at a constant temperature like a pure chemical. A large variety of PCMs are currently available, However they must exhibit correct operating temperature range, desirable thermodynamic, kinetic and chemical properties as well as reasonable costs to be effectively integrated in TES systems Organic compounds exhibit favorable characteristics such as congruent melting, low volume change, and non-corrosiveness. However, they also show low thermal conductivity, high flammability, varying level of toxicity and non-compatibility with certain plastic containers. Salt hydrates have high storage density and higher thermal conductivity as compared to paraffin's [Justin, 2007].

Molten salt can be employed as a thermal energy storage method to retain thermal energy collected by a solar tower or solar trough so that it can be used to generate electricity in bad weather or at night. It was demonstrated in the Solar Two project from 1995-1999. The system is predicted to have an annual efficiency of 99%, a reference to the energy lost by storing heat before turning it into electricity, versus converting heat directly into electricity. The molten salt is a mixture of 60 percent sodium nitrate and 40 percent potassium nitrate, commonly called saltpeter. It is non-flammable and nontoxic, and has already been used in the chemical and metals industries as a heat-transport fluid, so experience with such systems exists in non-solar applications.It also circulates through a central receiver, is heated by sunlight to more than 1,000 degrees, stored in a tank and dispatched into a steam generator. The steam drives a turbine that generates electricity. The cooled salt re-circulates and the process begins again.

The salt loses only 1% of its heat per day, which is far better than water and other materials the salt melts at 221 °C (430 °F). It is kept liquid at 288 °C (550 °F) in an insulated "cold" storage tank. The liquid salt is pumped through panels in a solar collector where the focused sun heats it to 566 °C (1,051 °F). It is then sent to a hot storage tank. This is so well insulated that the thermal energy can be usefully stored for up to a week.

When electricity is needed, the hot salt is pumped to a conventional steam-generator to produce superheated steam for a turbine/generator as used in any conventional coal, oil or nuclear power plant. A 10-megawatt turbine would need tanks of about 30 feet (9.1 m) tall and 80 feet (24 m) in diameter XMolten salt can be employed as a thermal energy storage method to retain thermal energy collected by a solar tower or solar trough so that it can be used to generate electricity in bad weather or at night. It was demonstrated in the Solar Two project from 1995-1999. The system is predicted to have an annual efficiency of 99%, a reference to the energy lost by storing heat before turning it into electricity, versus converting heat directly into electricity.

The major challenge of the molten salt is its high freezing point, leading to complications related to freeze protection in the solar field. The synthetic oil currently used freezes at about 15°C, whereas the ternary and binary molten salts freeze at about 120°C and 220°C, respectively. This demands innovative freeze protection methods and increased operation and maintenance (O&M) requirements [Kearney, 2002].

Operation during the charge and discharge cycles of molten-salt thermoclines used for solar thermal energy storage depends strongly on the environmental boundary conditions to which the tanks are exposed. A comprehensive model which accounts for thermal transport in the molten-salt heat transfer fluid and the filler material in the tank is developed for exploring the effects of boundary conditions on thermocline performance. Heat loss from the tank under non-adiabatic boundary conditions is found to distort the

temperature and salt flow distributions relative to the uniform conditions found in adiabatic thermoclines; as a result, the outflow temperature drops more rapidly in the former case [Zhen Yang, 2010].
The Purpose of energy storage is to store of some form of energy that can be drawn upon at a later time to perform some useful operation. All forms of energy are either potential energy, chemical or gravitational energy. Energy storage became a dominant factor in economic development with the widespread introduction of electricity and refined chemical fuels, such as gasoline, kerosene and natural gas in the late 1800s. Unlike other common energy storage used in prior use, such as wood or coal, electricity must be used as it is generated [Leonard, 2007].
The technology of thermal energy storage has been developed to a point where it can have a significant effect on modern life. The major nontechnical use of thermal storage was to maintain a constant temperature in dwelling, to keep it warm during cold winter nights. Large stones, blocks of cast iron, and ceramics were used to store heat from an evening fire for the entire night. With the advent of the industrial revolution, thermal energy storage introduced as a by-product of the energy production. A variety of new techniques of thermal energy storage have become possible in the past. A major application for thermal storage today is in family dwellings. Heat storage at power plants typically is in the form of steam or hot water and is usually for a short time. Very recently other materials such as oils, having high boiling point, have been suggested as heat storage substances for the electric utilities. Other materials that have a high heat of fusion at high temperatures have also been suggested for this application. Another application of thermal energy storage on the electric utilities is to provide hot water.
Perhaps the most promising application of thermal energy storage is for solar heated structures, and almost any material can be used for thermal energy storage.
We can calculate the amount of energy stored by using the following equation:

$$E = m\left[\left\{\int_{T1}^{T*} [cpsdT\} + \lambda + \left\{\int_{T*}^{T2} [cpldT\}\right]\right]\quad (2)$$

Where cps and cpl represents the specific heats of the solid and liquid phases and T* is the melting point and λ is the latent heat of fusion [ErcanAtaer, 2002].

Calculation of Heat Capacity of Dissolved Salts
Sample of calculation:
For heat capacity of NaCl solution if we use 7.4 gm of it which is dissolved in 250 gm of distilled water (i.e. NaCl wt. %=2.96%):

Cp for Na (by using table in [profmaster, 2009]) =28.2 kj/mol.k^o

Cp for Cl2=35.408 kj/mol.k^o

Therefore Cp for Cl=35.408/2=17.704 kj/mol.k^o

Cp for NaCl =28.2+17.704=45.904kj/mol.k^o

Molecular weight of NaCl=58g/mol.

Cp of NaCl=45.904/58=0.791kj/g.k^o=791kj/kg.k^o=791*0.23886=188.9kcal/kg.k^o

For water Cp=0.9975kcal/kg.k^o

Cp for NaCl solution=2.96*188.9/100+97.04*0.9975/100=6.55 kcal/kg.k^o

By the same way Cp for NaHCO3=8.81kcal/kg.k^o

All the values of Cp for the two salts at different weight percent are listed in table (4)

Results and Discussion

An experimental investigation for the solar energy saving by using pure sodium chloride or sodium bicarbonate salts which are added individually to 250 gm of distilled water(in conical flask) with different adding's (concentrations),during 45 minutes for losing the heat gained from the sun ,then we calculate the decreasing in temperature after the sun set. Figure (1) represent the relationship between the decreasing temperature with heat losing time for distilled water, in which we saw that temperature is decreases from 50 to 41 C^o during 45 minutes.

Figure (2) also represents the relationship between the decreasing temperature with heat losing time for the adding of 7.4gm (2.96 wt. %) of each NaCl or NaHCO3, from which we saw that the temperature is decreases from 50 to 42 C^o during 45 minutes for NaCl solution, while from 49 to 42.2 C^o for NaHCO3 solution, i.e. the later salt is saving energy greater than the first salt. Also the same behavior for figure (3).
While for figures (4-10) the temperatures are decrease with time, but we saw the curves of NaCl solution in all these figures has the greater value than the curves of NaHCO3 solution.
Figure(11) shows the relationship between heat capacity for dissolved NaCl or NaHCO3 solution for different weight percent, one can observe that the heat capacity of the two salts are increasing with increasing their weight percent, and the heat capacities of NaHCO3 solution are greater than the heat capacities for NaCl solution.

Conclusions

From the present work, we deduce the following conclusions:
1. The temperatures of NaCl or NaHCO3 solution are decreased with time.
2. The temperatures of distilled water are rapidly losing the heat gained from the sun faster than the salt solutions.
3. The heat capacities of the two salts are increasing with increasing their weight percent.
4. The heat capacities of NaHCO3 solution are greater than the heat capacities for NaCl solution.

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Table(1) Temperature($C^{0)}$of NaCl Solution with time (minute)

sample	0min.	5min.	10min.	15min.	20min.	25min.	30min.	35min.	40min.	45min.
1	50	47	46	45	44	43	42	42	41	41
2	50.0	48.5	47	45.5	45	44.8	44.2	43.8	43	42
3	49.5	47.7	46	45	44	43	42.5	41.8	41.5	41
4	51	50	48	47	46	45	44.9	43.9	43.4	43
5	52	50.5	49.6	48.3	48	46.6	46.2	45.6	44.9	44.5
6	53	52	52	51	50	49	48	47	47	47
7	50	48.5	47.2	46	45.1	44.6	43.8	43	42.5	42.1
8	52	50	49	48	46	46	45	45	44	43.8
9	51	49	48.4	47.1	46	45.5	45	44.4	44	42.6
10	52	50.8	49.5	47.8	46.8	46	45.4	45	45	45

Table (2) Temperature (C^0) of NaHCO3Solution with time (minute)

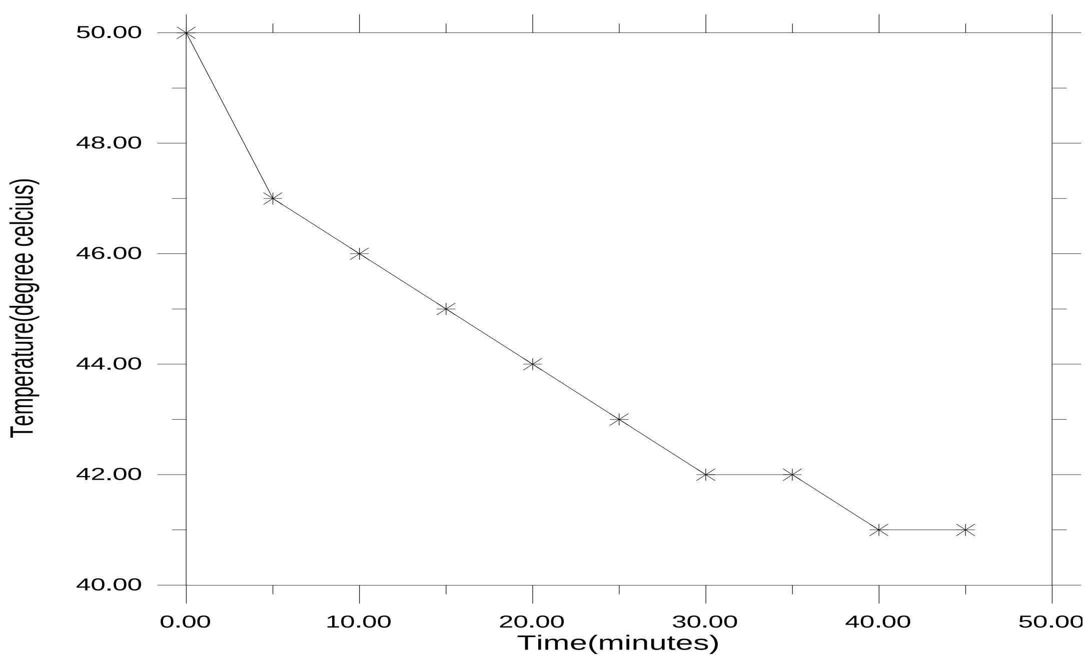
sample	0min.	5min.	10min	15min	20min	25min	30min	35min	40min	45min.
1	50	47	46	45	44	43	42	42	41	41
2	49	49	48	47	45.5	45	44	43.2	43	42.2
3	48	48	46.5	46	46.5	45.5	45.5	44.5	43.5	43
4	48	48	46	45	43.8	43	42	41	40.5	40
5	50	47	45.5	45	44	43	42	41.5	41	40
6	48	45.5	45	45	44	43	42.5	41.5	41	40
7	45	44.5	42	41.5	40.6	40	39	38.5	38	37.5
8	44	43	42	41.5	41	40	39	39	38.4	38
9	44	43.5	41.5	41	40	39.6	39	38.2	38	37.5
10	45	44.8	43	43	42	41	40.5	40	39.8	39

Table (3) Concentrations of the Sample used of NaCl and NaHCO3 Solutions

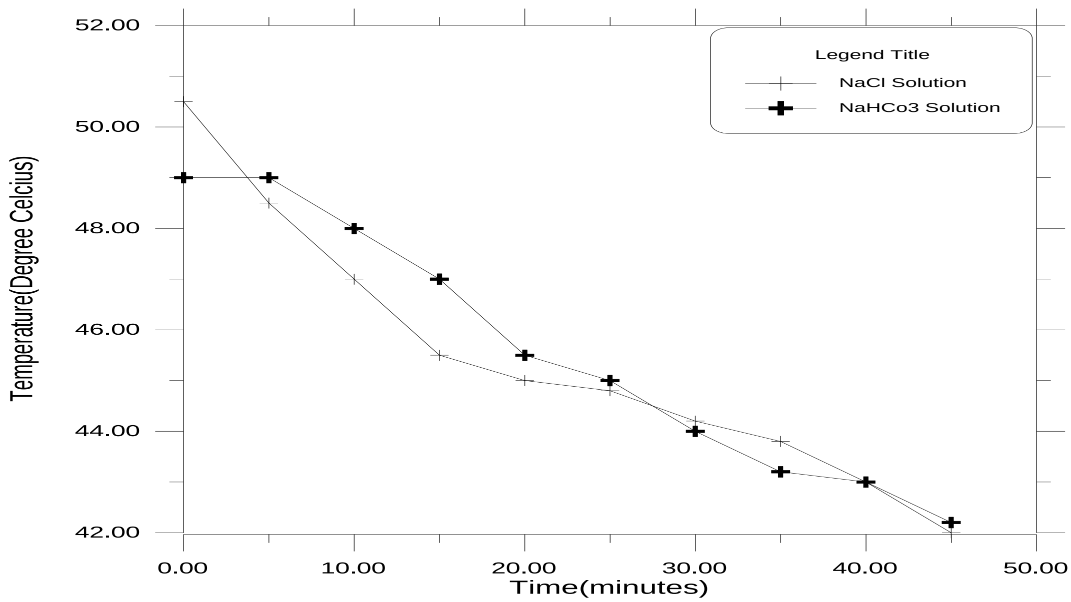
Sample	1	2	3	4	5	6	7	8	9	10
Concentration (mole/m^3)	Distilled water	508	1016	1524	2032	2540	3048	3556	4064	4572

Table (4) Heat Capacities of NaCl and NaHCO3 Solutions at Different wt.%

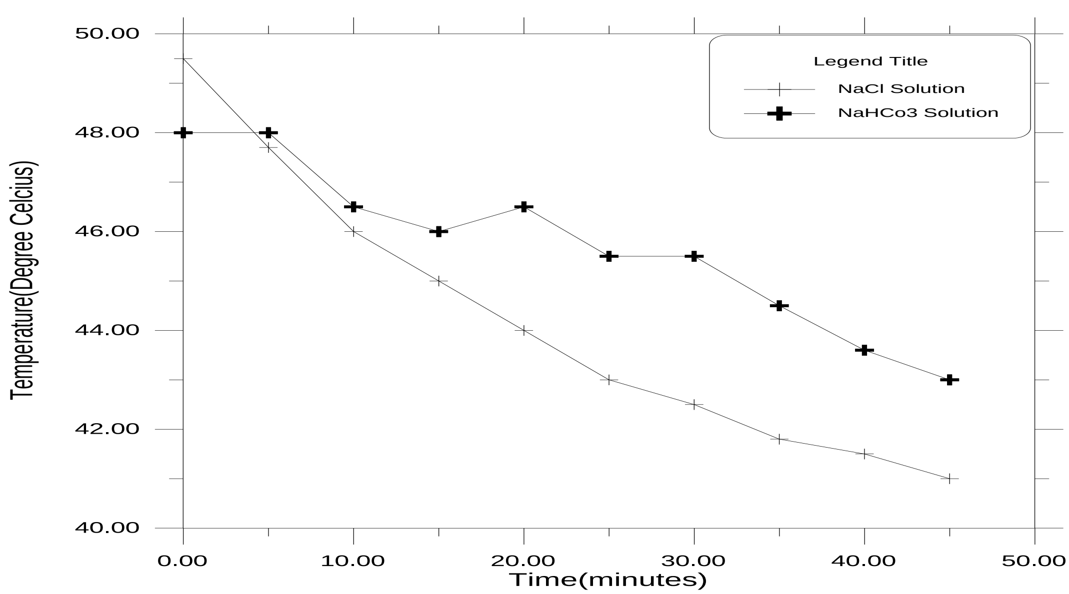
Salts wt. %	Cp of NaCl(kcal/kg.k^o)	Cp of NaHCO3(kcal/kg.k^o)
2.96	6.55	8.81
5.9	12.02	16.53
8.88	17.6	24.44
11.8	23.06	32.1
14.8	28.7	40.06
17.76	34.2	47.88
20.7	39.7	55.6
23.67	45.2	63.5
26.64	50.9	71.3



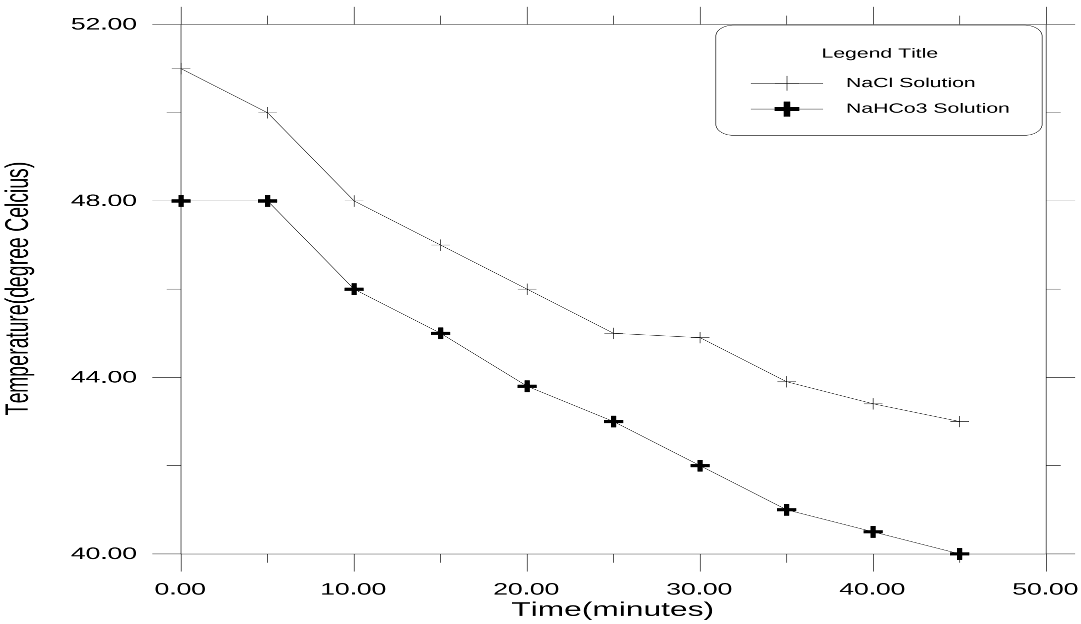
Figure(1) Variation of Temperature of distilled water with Time



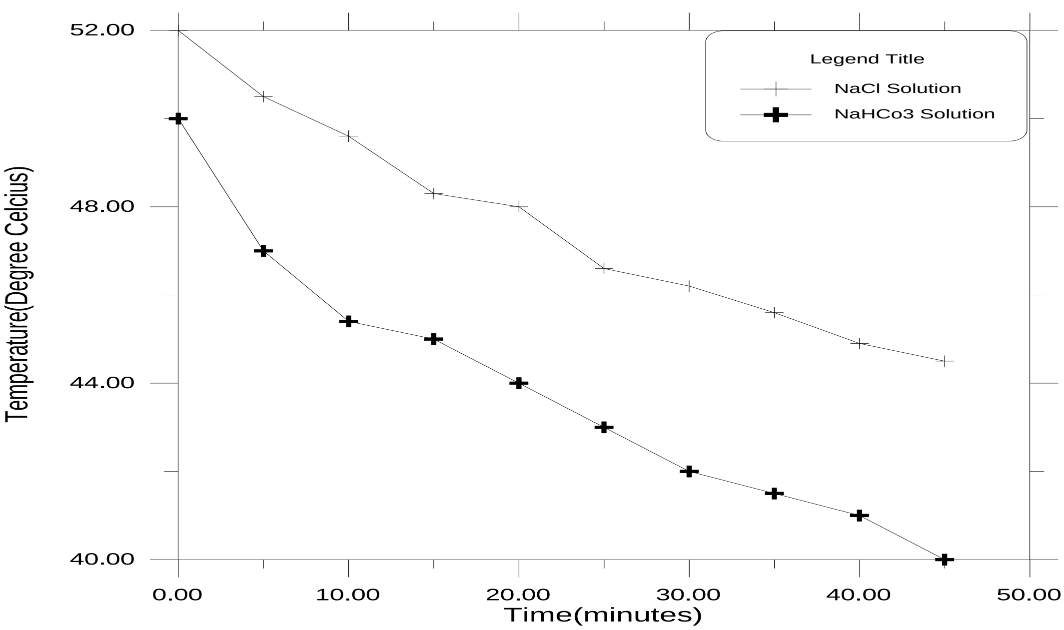
Figure(2) Variation of Temperature with Time for Salts Concentration of 508 mole/m3



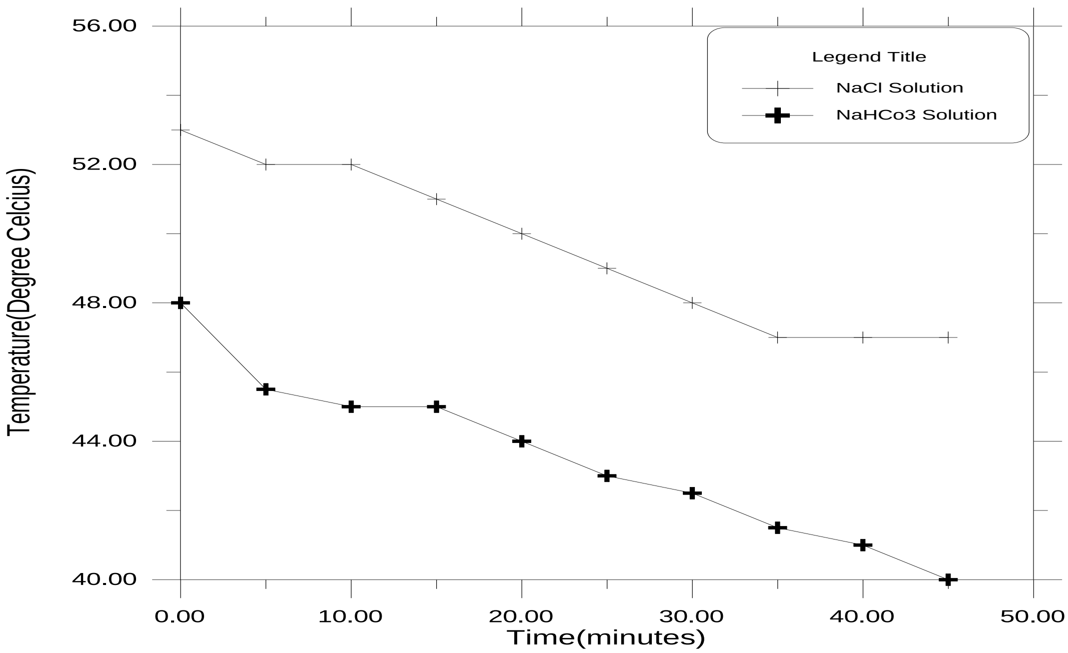
Figure(3) Variation of Temperature with Time of Salts Solution for the Concentration of 1016 mole/m3



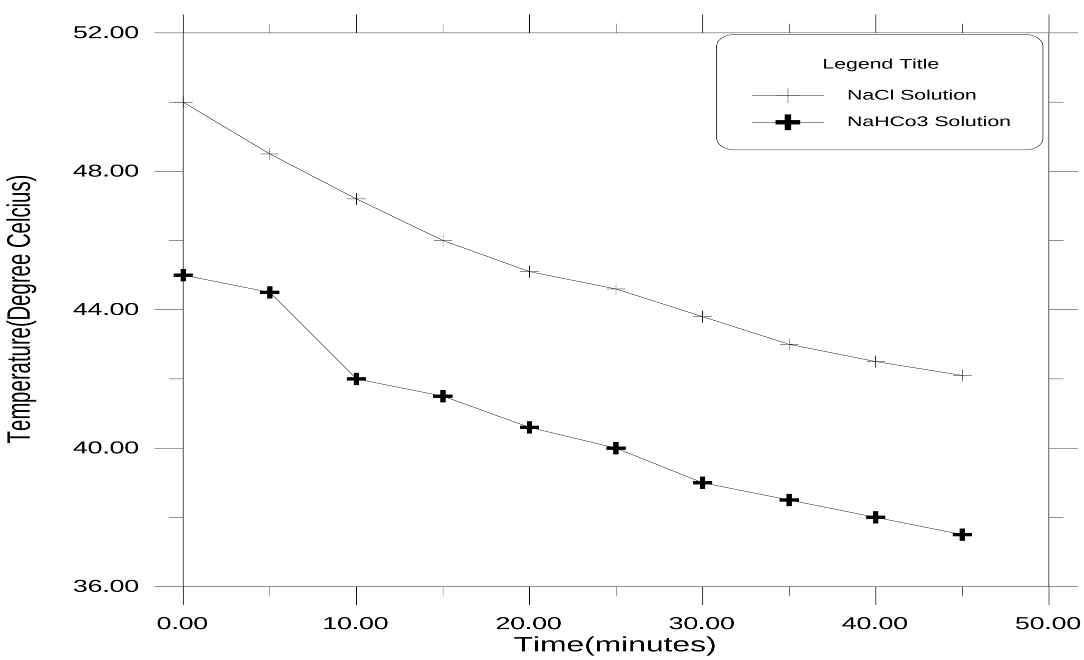
Figure(4) Variation of Temperature with Time for the Salts Concentration of 1524 mole/m3



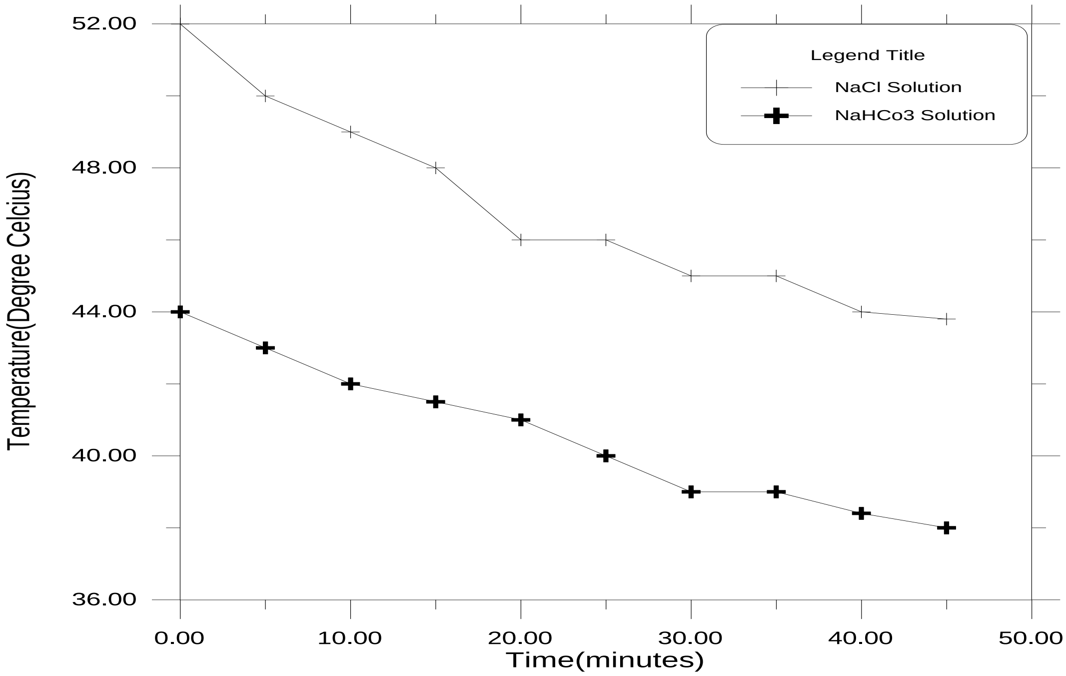
Figure(5) Variation of Temperature with Time for the Salts Solution Concentration of 2032 mole/m3



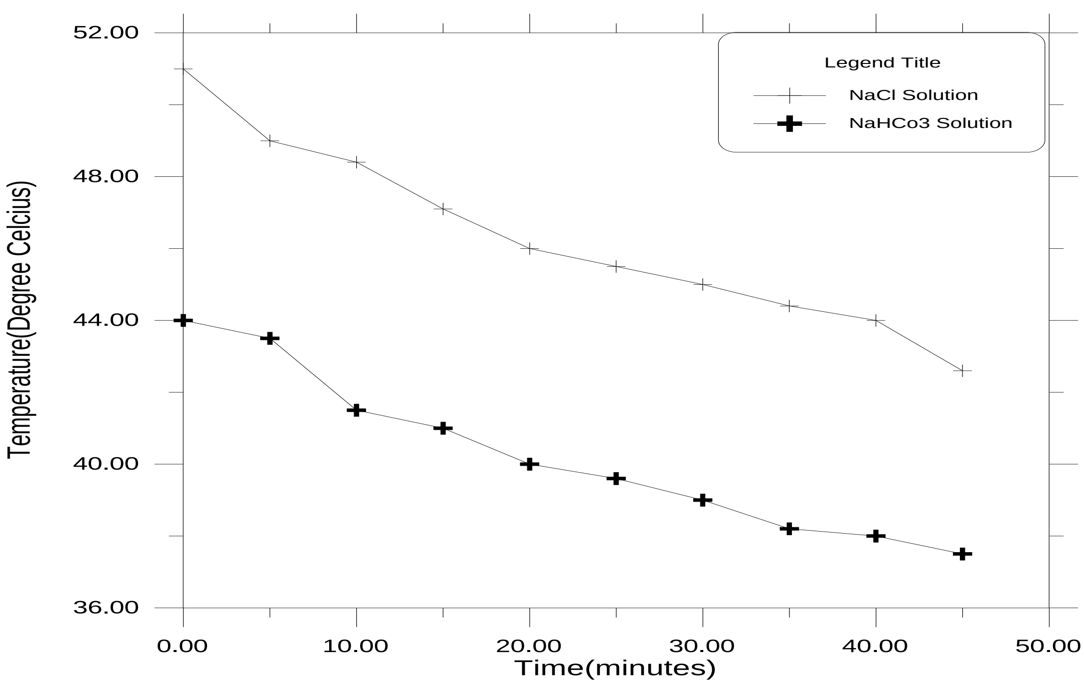
Figure(6) Variation of Temperature with Time for the Salts Solution Concentration of 2540 mole/m3



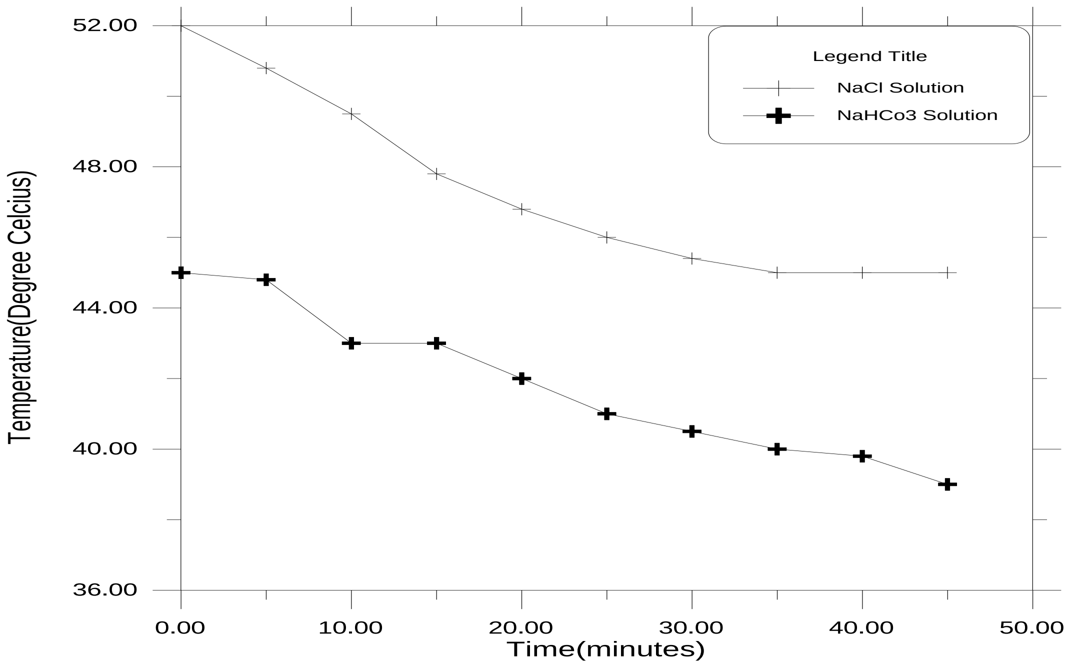
Figure(7) Variation of Temperatue with Time for the Salts Solution Concentration of 3048 mole/m3



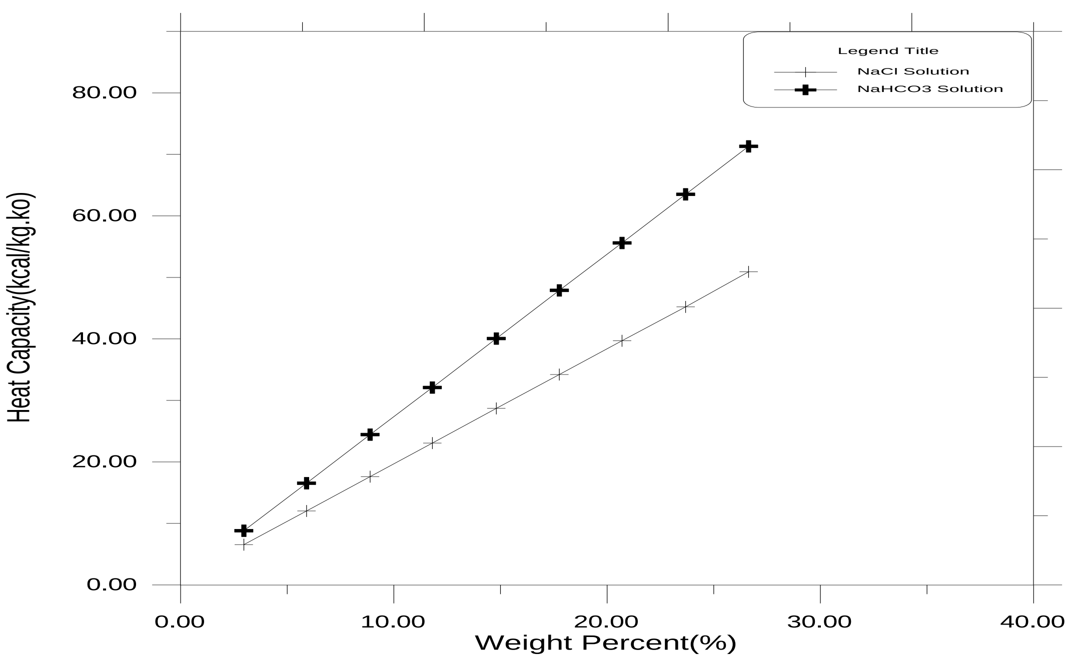
Figure(8) Variation of Temperature with Time for the Salts Solution Concentration of 3556 mole/m3



Figure(9) Variation of Temperature with Time for the Salts Solution Concentration of 4064 mole/m3



Figure(10) Variation of Temperature with Time for the Salts Solution Concentration of 4572 mole/m3



Figure(11) Variation of Heat Capacity of NaCl and NaHCo3 Solutions with it Weight Percent