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Compressor Engineering
Refrigeration and Air Conditioning
High Performance Buildings

Experimental study on a solar-powered thermochemical sorption refrigeration system using strontium chloride/EG-ammonia working pair

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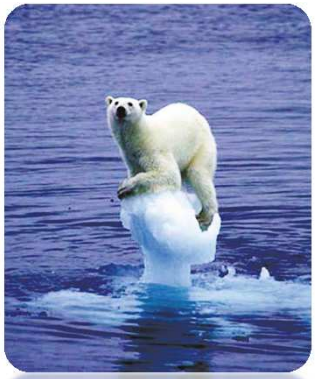
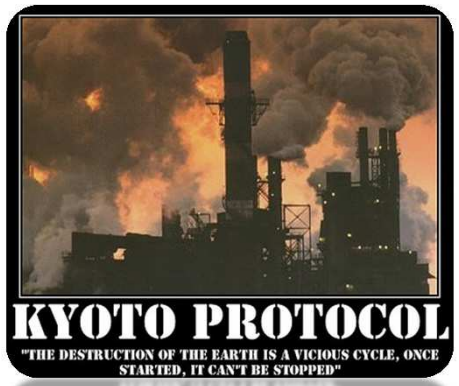
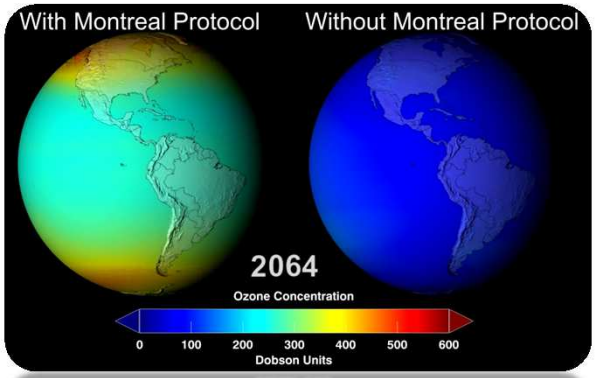
1. INTRODUCTION







Electric energy → Global warming

Solar energy, industrial waste heat

Adsorption Refrigeration

- **Simple structure**
- **Low maintenance**
- **Easy control**
- **Less noise**

CFCs' and HFCs' → Ozone depletion

Water, methanol, ammonia

1. INTRODUCTION

Silica gel–water
Zeolite–water
adsorption chillers
commercialized

→ ~~**Freezing condition**~~

→ **Low specific cooling power**

↓

Chemical adsorbent-ammonia

→ **Poor heat and mass transfer**

↓

Composite adsorbent-ammonia

→ **$CaCl_2$/AC, $SrCl_2$/EG, $BaCl_2$/EG, $BaCl_2$/vermiculite……**

↓

$CaCl_2$/AC ice maker
$SrCl_2$/EG refrigeration system

→ **Small scale**
High reliability

$$SrCl_2 \cdot NH_3 + 7NH_3 \underset{\text{decomposition}}{\overset{\text{synthesis}}{\rightleftharpoons}} SrCl_2 \cdot 8NH_3 + \Delta H_r$$

2. EXPERIMENT SYSTEM

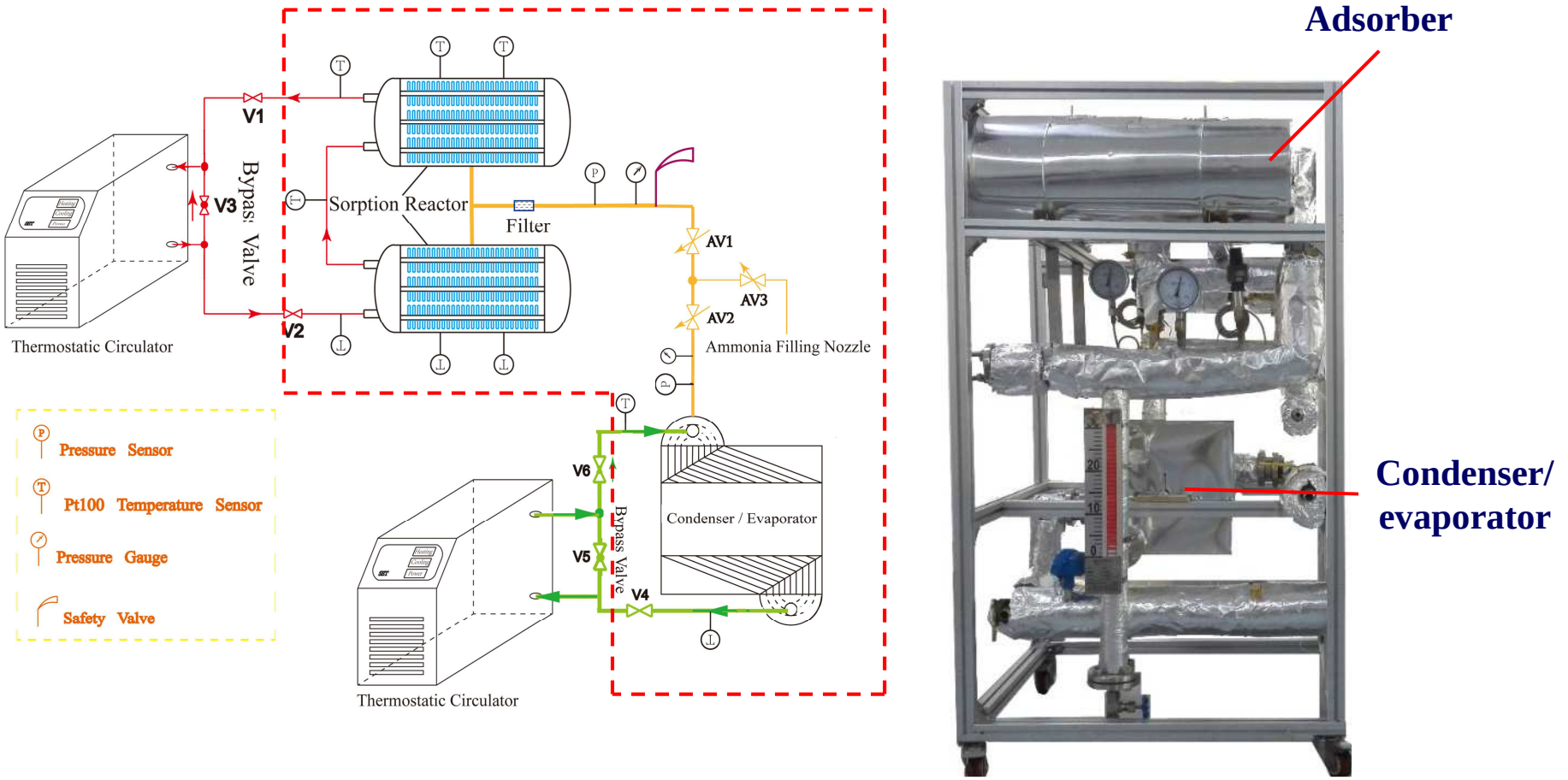


Figure 1. Experiment system, (a) the overall schematic of system; (b) the photograph of the main part

2. EXPERIMENT SYSTEM

Composite adsorbent: $SrCl_2$+EG (impregnation method)

Adsorber

- Two sub adsorbers
- Steel shell-tube type
- 10 finned tubes

(a) filled with composite adsorbent

(b) covered with wire mesh

(c) the reactor without thermal insulation material

2. EXPERIMENT SYSTEM

Table 1: Construction details of the reactor

Parameters	Value
Number of fin for every finned tube	149
Fin thickness	0.4 mm
Fin length	9.5 mm
Distance between fins	5 mm
Number of heat exchange tube	20
Inner diameter of heat exchange tube	Ø10mm
outer diameter of heat exchange tube	Ø16mm
length of every heat exchange tube	860mm
Inner diameter of shell	Ø151mm
Mass of salt (m_s)	3.73 kg
Mass of expanded graphite (m_{EG})	0.65 kg
Inert material/composite sorbent heat capacity ratio (R_{Cp})	11.8
Thickness of the adsorber case wall	4 mm
Pressure loading capacity of the reactor case wall	3.0 MPa

Table 2: Specifications of the measuring sensors

Equipment	Specification	Quantity	Accuracy
Temperature sensor	PT100 (-50~450°C)	9	±0.15 °C
Pressure sensor	0~4 MPa	2	0.5%
Pressure gauge	0~3.6Mpa	2	2.5%

2. EXPERIMENT SYSTEM

Coefficient of performance (COP) and specific cooling power (SCP)

The COP is calculated with Equation (2), whereas the SCP is calculated using Equation (3):

$$COP = \frac{Q_{Ev}}{Q_{Ds}}$$

$$SCP = \frac{Q_{Ev}}{m_S t}$$

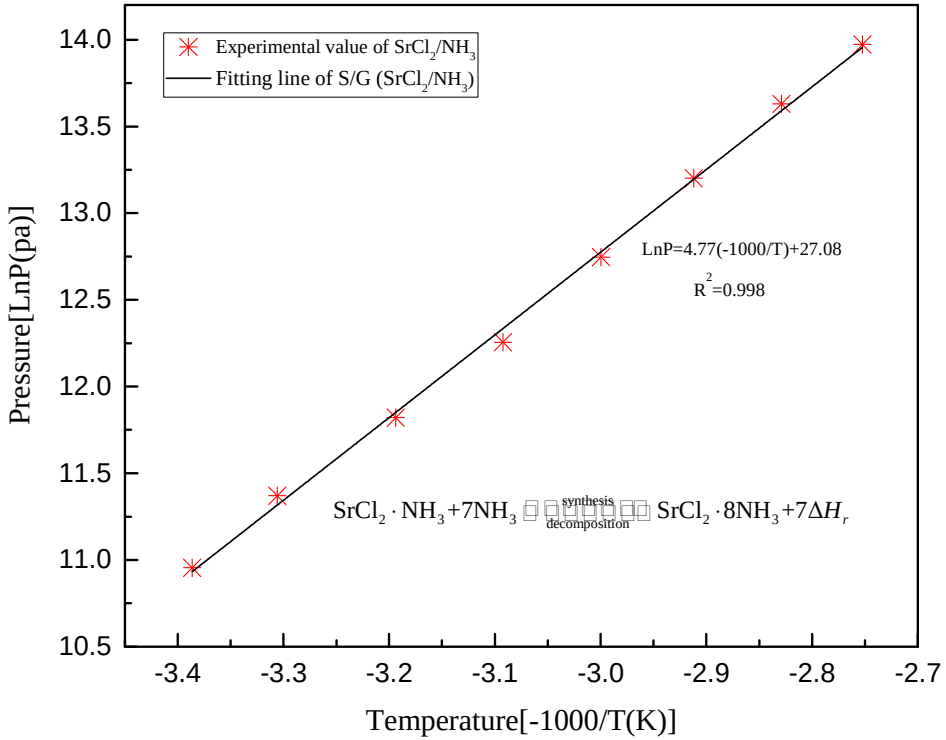
Where m_s is the mass of the salt (kg), t is the evaporation time(s), Q_{Ev} and Q_{Ds} are determined from the following equations, respectively:

$$Q_{Ev} = \sum_{i=0}^{200} \overset{g}{m}_{Ev} C_p (T_{Ev,in} - T_{Ev,out})_i \Delta t$$

$$Q_{Ds} = \sum_{i=0}^{400} \overset{g}{m}_{Ad} C_p (T_{Ad,in} - T_{Ad,out})_i \Delta t$$

where $\overset{g}{m}$ is the mass low rate of the heat transfer fluid, C_p is the specific heat capacity of heat transfer fluid. Δt is equal to 6 seconds.

3. RESULTS AND DISCUSSION



$$\ln P = -\frac{4770}{T} + 27.08$$

$$\ln P = -\frac{\Delta H_r}{RT} + \frac{\Delta S_r}{R}$$

Figure 2. The equilibrium pressure of the reactor at different temperatures

Reactant	ΔH(kJ/mol)	ΔS[kJ/mol K]	Reference
$SrCl_2/NH_3$(8-1)	39.66	225.16	Present study
	41.43	228.80	(Neveu and Castaing, 1993)

3. RESULTS AND DISCUSSION

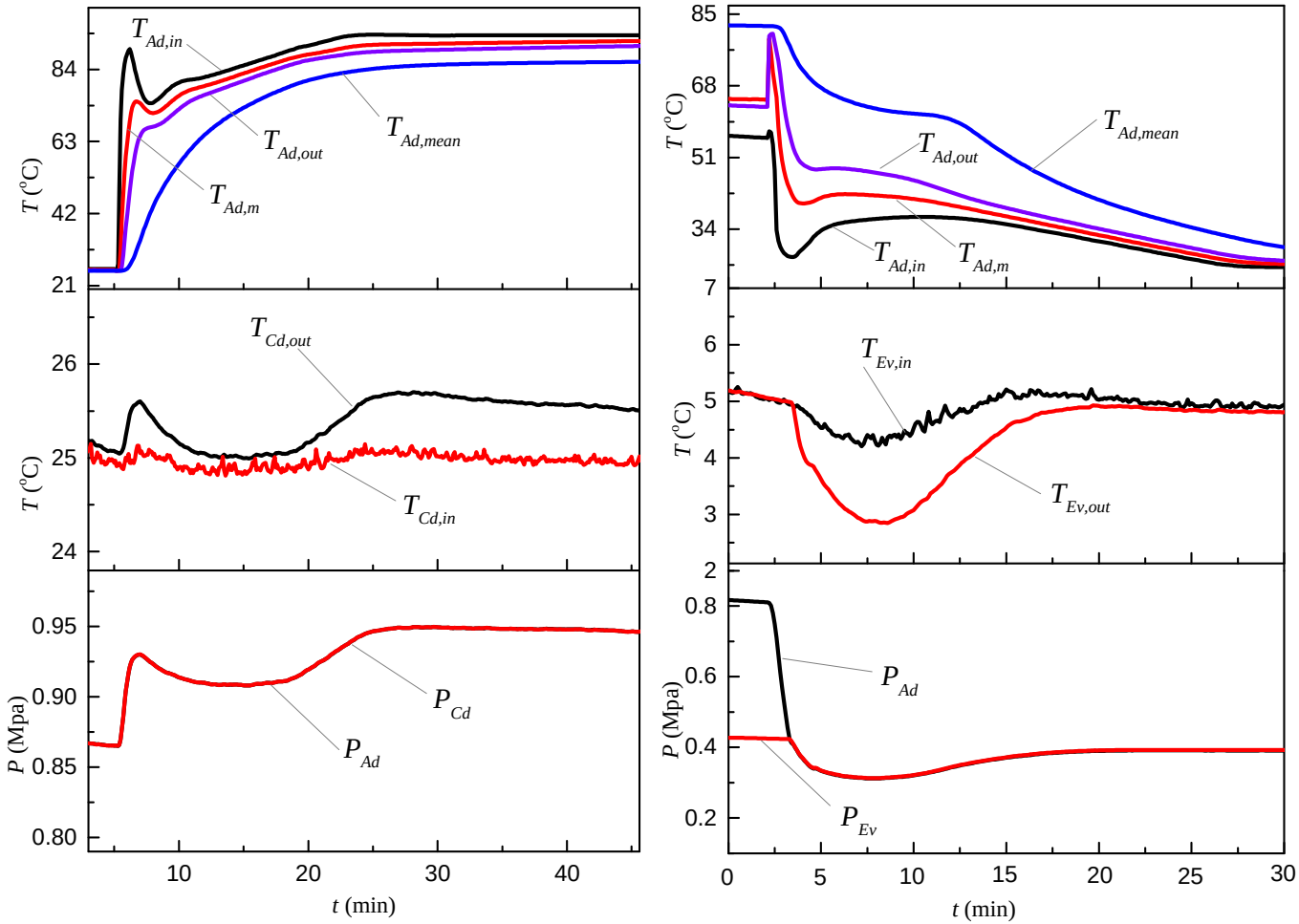
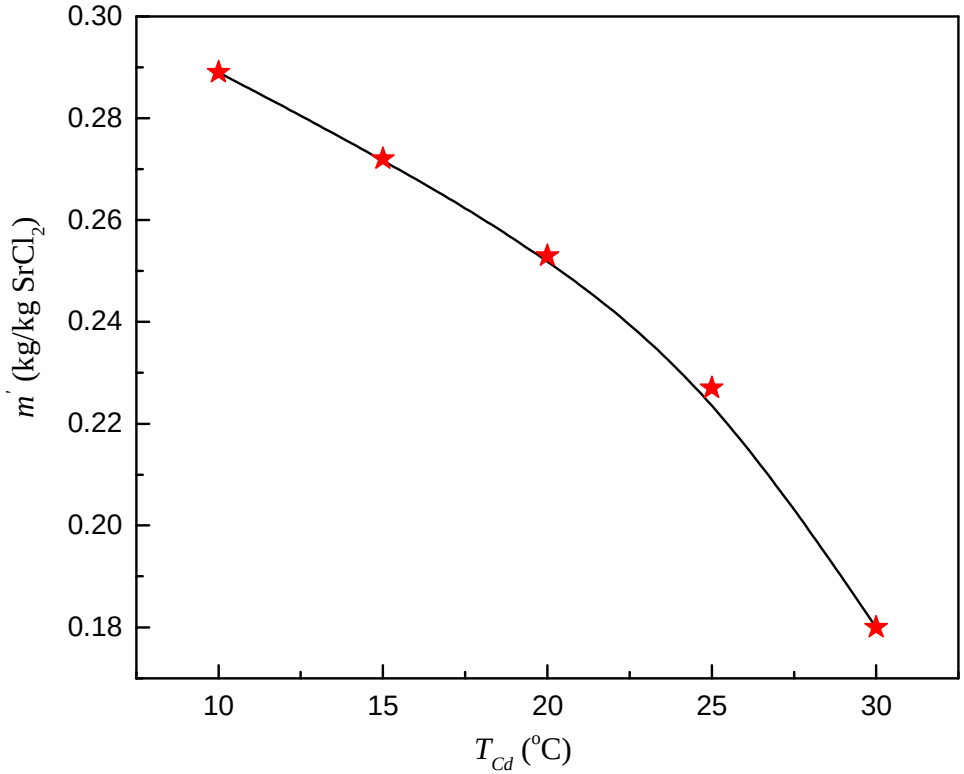


Figure 3. The temperature and pressure profiles of adsorber and condenser/evaporator in (a) regeneration, and (b) adsorption stage

3. RESULTS AND DISCUSSION

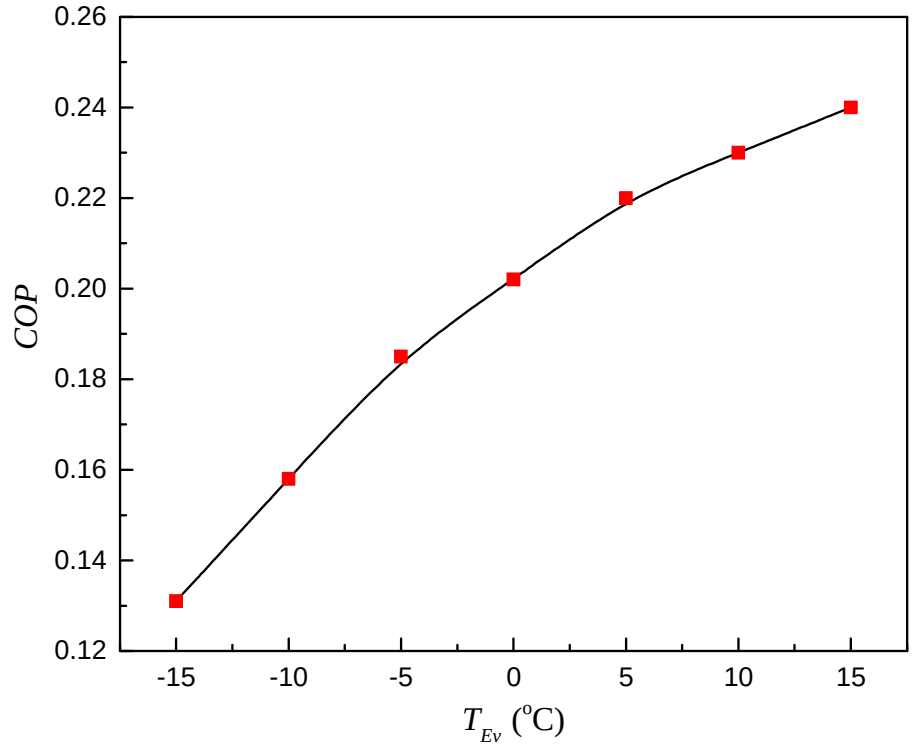
Heat source temperature: 94±1.5°C; Desorption time: 40 min



Effect of the condensation temperature on the desorption mass of NH_3

3. RESULTS AND DISCUSSION

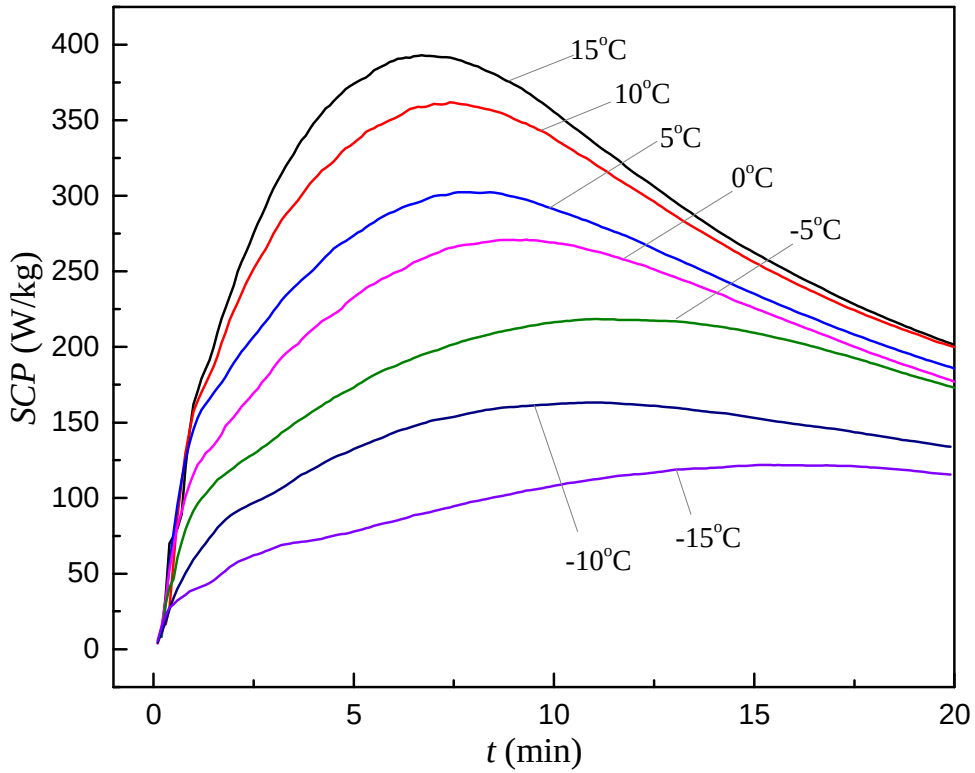
Heat source temperature: 94±1.5°C; Condensation temperature: 25°C
Ambient temperature: 25°C; Desorption time: 40 min; Adsorption time: 20 min



Effect of the evaporation temperature on the COP

3. RESULTS AND DISCUSSION

Heat source temperature: 94±1.5°C; Condensation temperature: 25°C
Adsorption temperature: 25°C; Desorption time: 40 min; Adsorption time: 20 min



Effect of the evaporation temperature on the SCP

4. CONCLUSION

1. **An intermittent thermochemical refrigeration system using $SrCl_2$/EG as composite sorbent and ammonia as refrigerant was constructed and studied from the view of practical application**

2. **The sorption characteristic, the reaction enthalpy and entropy of $SrCl_2/NH_3$ was investigated experimentally.**

3. **The system could utilize effectively solar energy with temperature about 94 ^oC and output the cooling capacity. The COP obtained varied between 0.13 and 0.24. The mean SCP increased from 98.6 to 291.5W/kg(The value of physical adsorption icemaker using consolidated activated carbon–methanol as working pair in which COP and SCP were 0.125 and 32.6 W/kg, respectively)**