



HAL
open science

Experimental and Computational Investigation on the Glyceline – CO₂ Working Fluid in Absorption Chiller

Cesari Laetitia, Dominique Alonso, Fabrice Mutelet

► **To cite this version:**

Cesari Laetitia, Dominique Alonso, Fabrice Mutelet. Experimental and Computational Investigation on the Glyceline – CO₂ Working Fluid in Absorption Chiller. 8th International Congress on Ionic Liquids, May 2019, Pekin, China. hal-03480333

HAL Id: hal-03480333

<https://hal.univ-lorraine.fr/hal-03480333>

Submitted on 4 Apr 2023

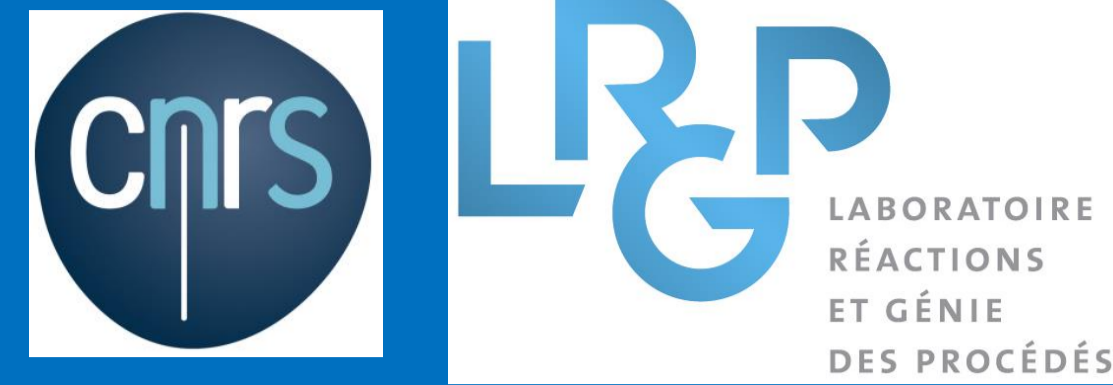
HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Experimental and Computational Investigation on the Glyceline – CO₂ Working Fluid in Absorption Chiller



Laëticia CESARI, Dominique ALONSO, Fabrice MUTELET
 Université de Lorraine - École Nationale Supérieure des Industries Chimiques - LRGP,
 54000 Nancy - France
 laetitia.cesari@univ-lorraine.fr

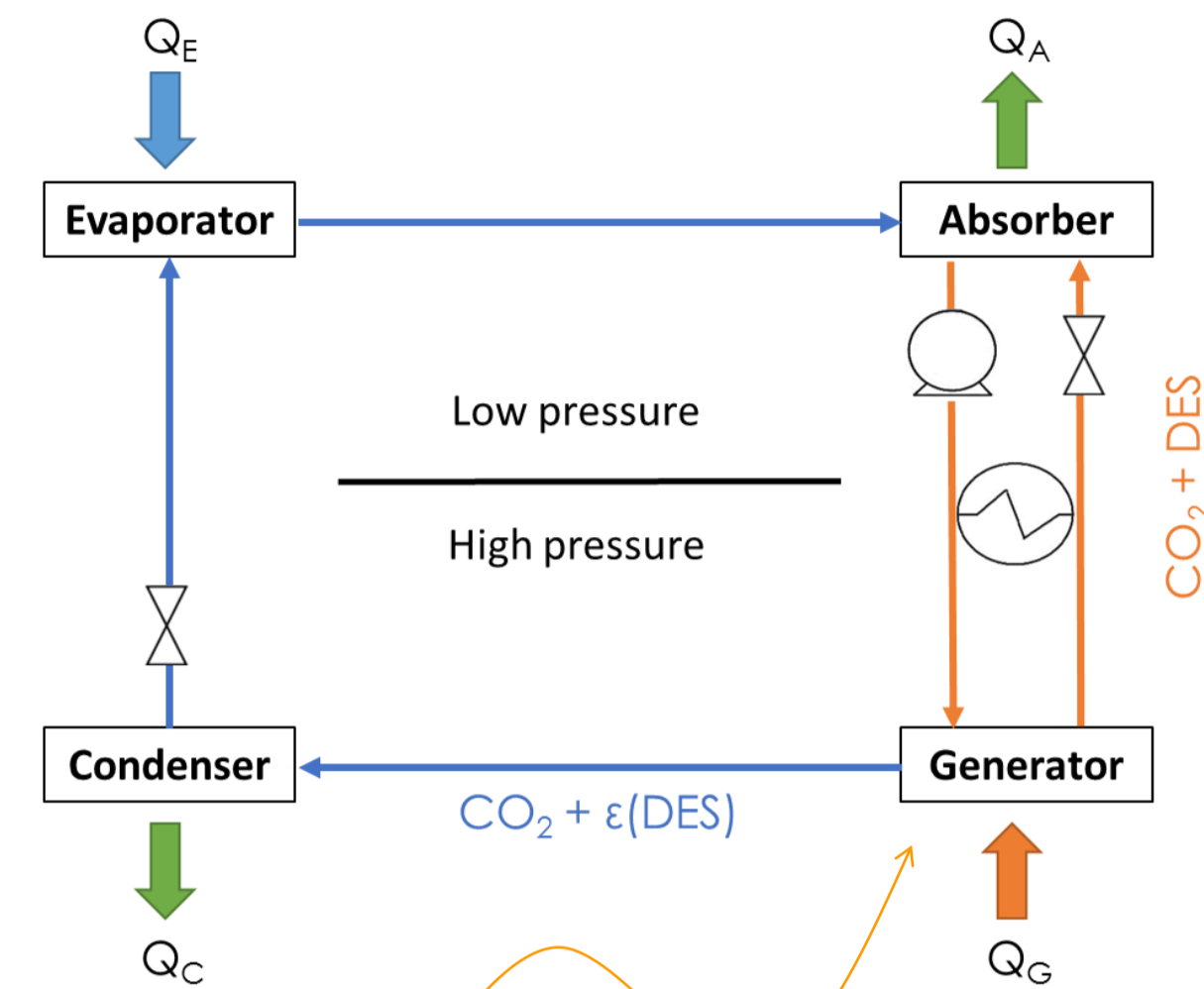


Introduction

Absorption chiller
 Double thermodynamic cycle
Absorbent and **refrigerant**
 Cooling process by using wasted heats
 Low electric consumption



Usual working mixtures :
 {H₂O + LiBr} or {H₂O + NH₃}
 Effective **BUT** problems of corrosion,
 crystallization and toxicity



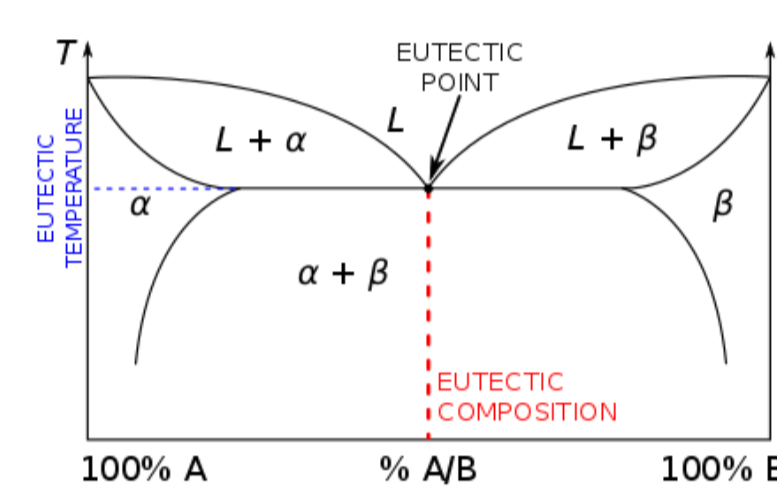
Idea: use of deep eutectic solvent as absorbent

Deep Eutectic Solvent (DES)

Mixing of compounds at the eutectic composition

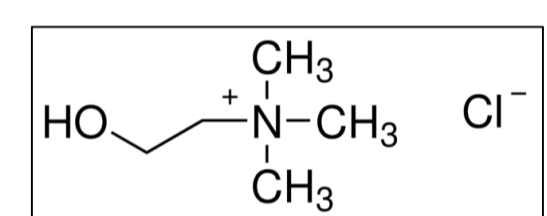
Properties of DES:

Low vapor pressure
 High thermal and chemical stability
 Cheaper than ionic liquids

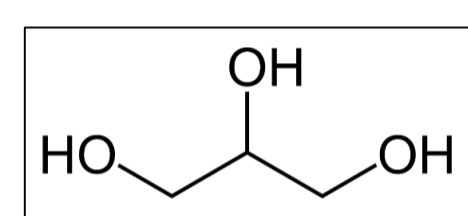


Our working mixture: Glyceline + CO₂

Glyceline : 1 choline chloride + 2 glycerol



choline chloride



glycerol

Experimental measurements

Density



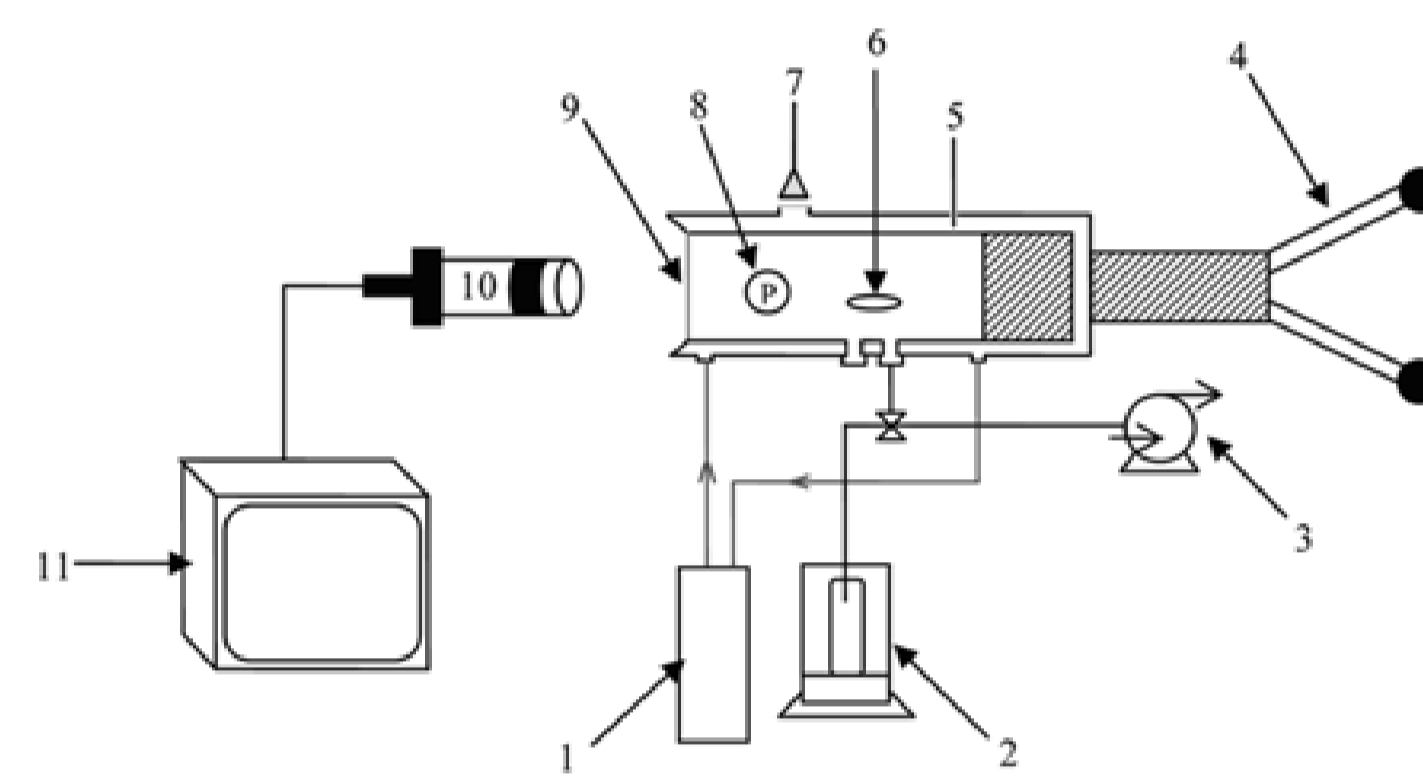
Anton Paar DMA 4500 density meter
 Principe based on electromagnetically induced oscillations of a U-shaped glass tube
 Temperature range : 293.15 – 313.15 K

Heat Capacity



C80 calorimeter
 Comparison of the heat flow signal between the reference and the sample cells
 Temperature range : 310.15 – 370.15 K

Vapor – Liquid Equilibria



Schema of the VLE apparatus. 1, thermostatic bath; 2, analytical balance; 3, vacuum pump; 4, piston; 5, temperature probe (Pt100); 6, magnetic stirrer; 7, light source; 8, calibrated pressure sensor (0 < P < 340 bar); 9, sapphire window; 10, video camera; 11, monitor.

Simulation

Peng - Robinson equation of state

$$P = \frac{RT}{v-b} - \frac{a}{v(v+b)+b(v-b)}$$

With :

$$b_i = \Omega_b \frac{RT_{c,i}}{P_{c,i}}$$

$$R = 8.314472 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$$

$$\Omega_b = 0.0777960739$$

$$a_i = \Omega_a \frac{R^2 T_{c,i}^2}{P_{c,i}} \left[1 + m_i \left(1 - \sqrt{\frac{T}{T_{c,i}}} \right) \right]^2$$

$$\Omega_a = 0.457235529$$

Mixing rules of **Van der Waals**

$$a = \sum_{i=1}^n \sum_{j=1}^n z_i z_j \sqrt{a_i a_j} (1 - k_{ij}(T))$$

$$b = \sum_{i=1}^n x_i b_i$$

Critical properties of DES components estimated using the **Lydersen-Joback-Reid** method

$$T_b = 198.2 + \sum n_i \Delta T_{bMi}$$

$$V_c = 6.75 + \sum n_i \Delta V_{Mi}$$

$$T_c = \frac{T_b}{0.5703 + 1.0121 \sum n_i \Delta T_{Mi} - (\sum n_i T_{Mi})^2}$$

$$P_c = \frac{M}{(0.2573 + \sum n_i \Delta P_{Mi})^2}$$

DES properties using the mixing rules of **Lee-Kesler**

$$T_{cDES} = \frac{1}{V_{cDES}^{0.25}} \sum_i \sum_j y_i y_j V_{cij}^{0.25} T_{cij}$$

$$T_{cij} = (T_{ci} T_{cj})^{0.25} k'_{ij}$$

$$V_{cDES} = \sum_i \sum_j y_i y_j V_{cij}$$

$$V_{cij} = \frac{1}{8} \left(V_{ci}^{\frac{1}{3}} + V_{cj}^{\frac{1}{3}} \right)^3$$

$$P_{cDES} = (0.2905 - 0.085 \omega_D) \frac{RT_{cDES}}{V_{cDES}}$$

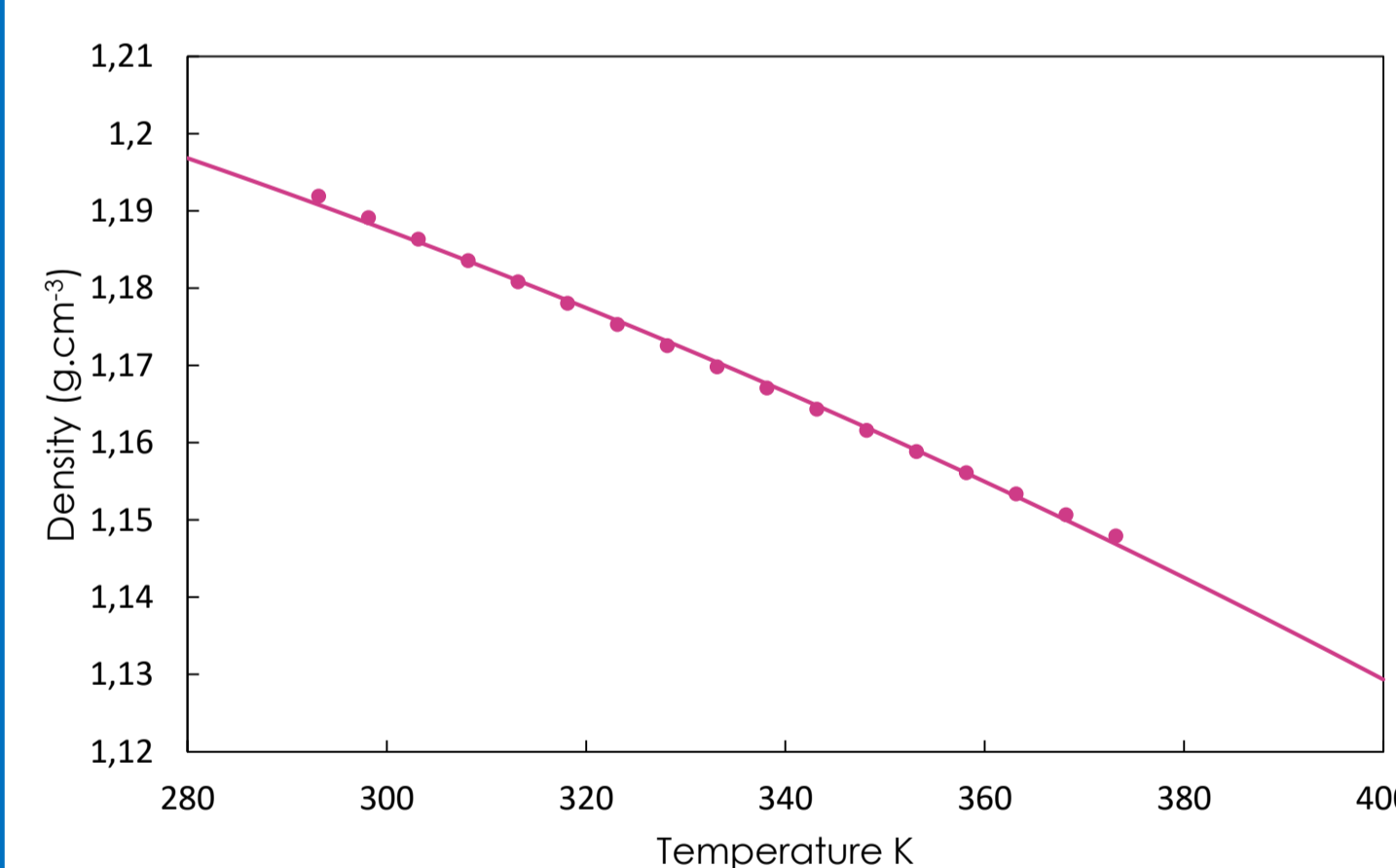
$$\omega_D = \sum_i y_i \omega_i$$

Coefficient of performance

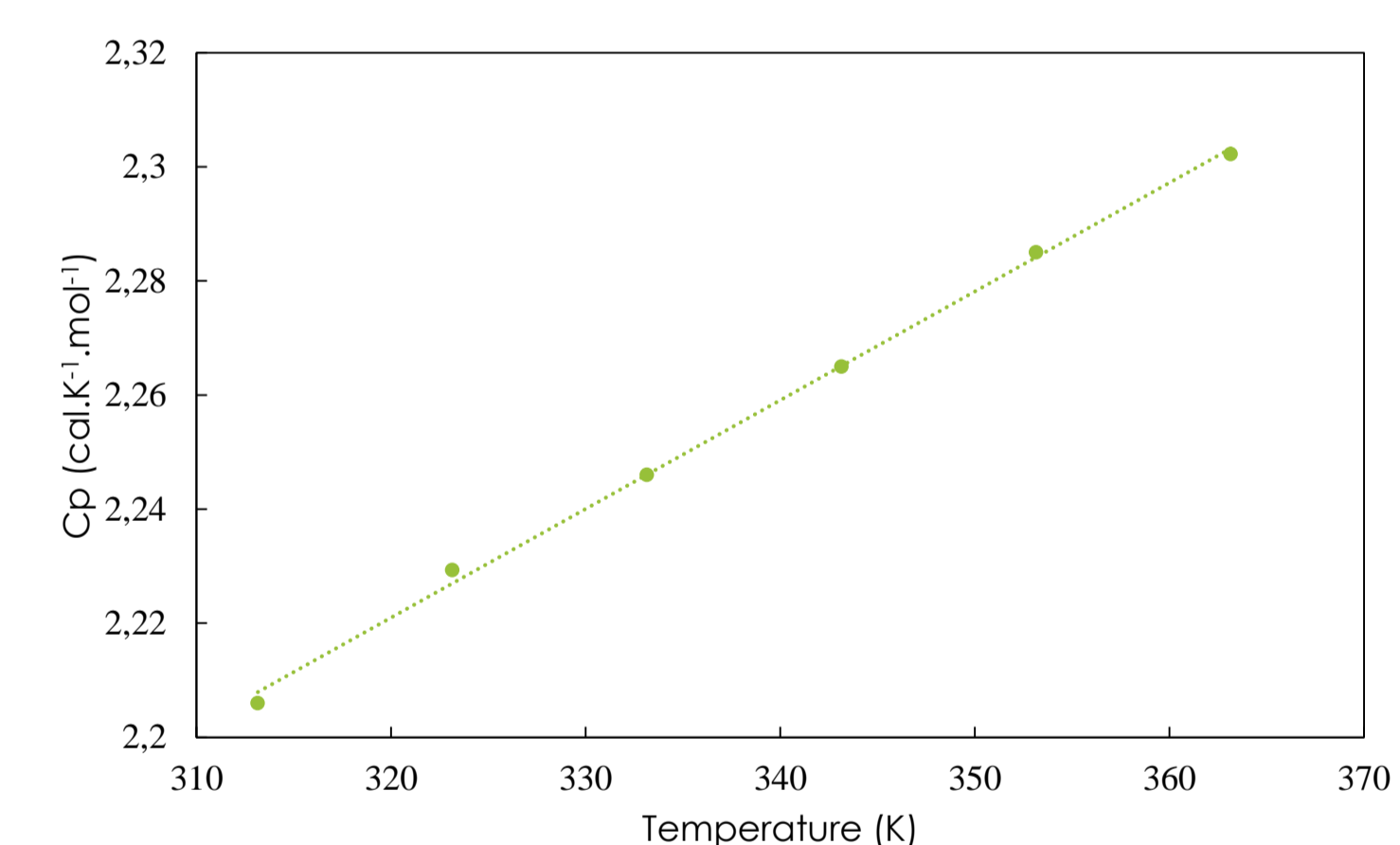
$$COP = \frac{Q_E}{Q_G + W}$$

Results

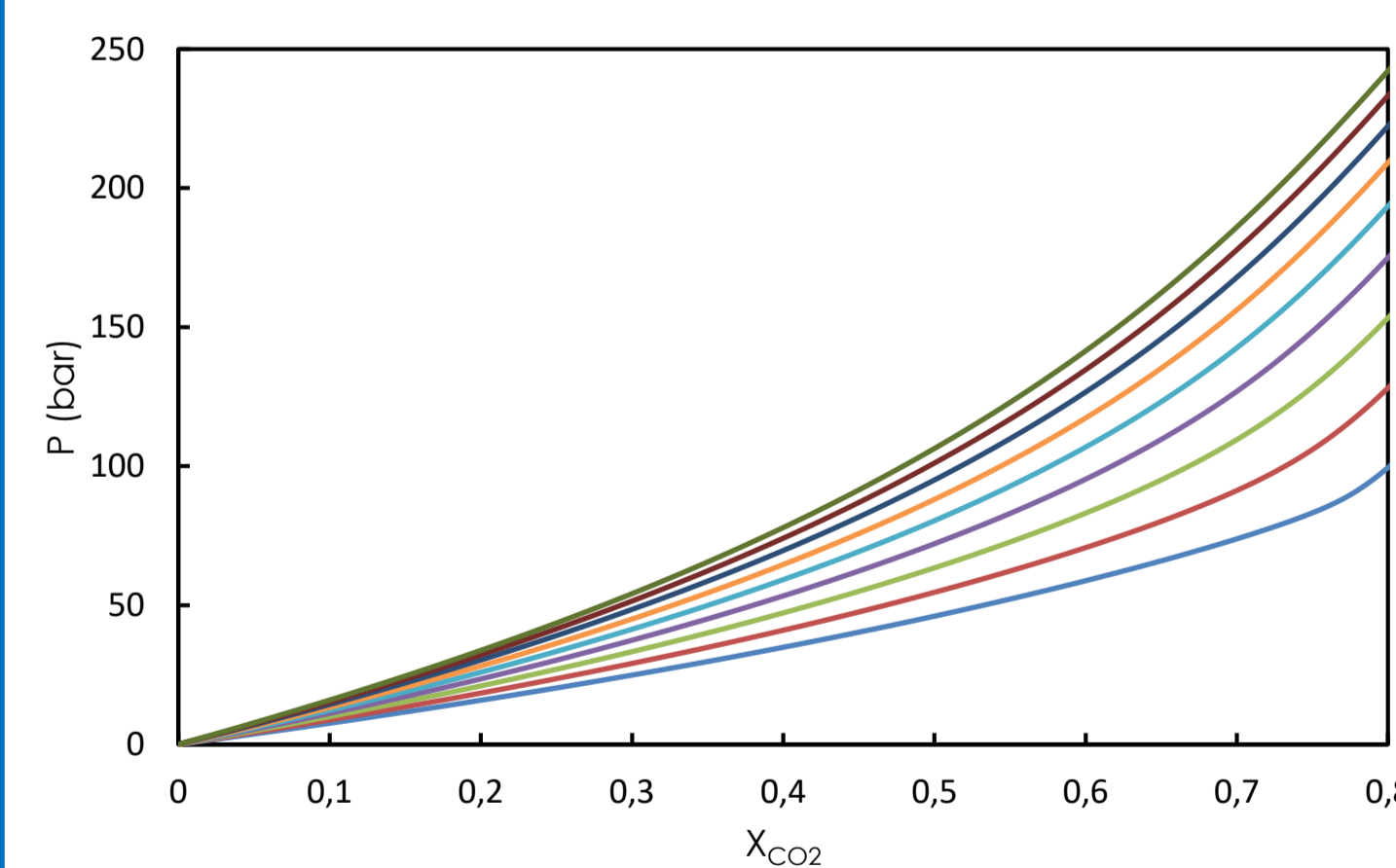
Density



Heat Capacity

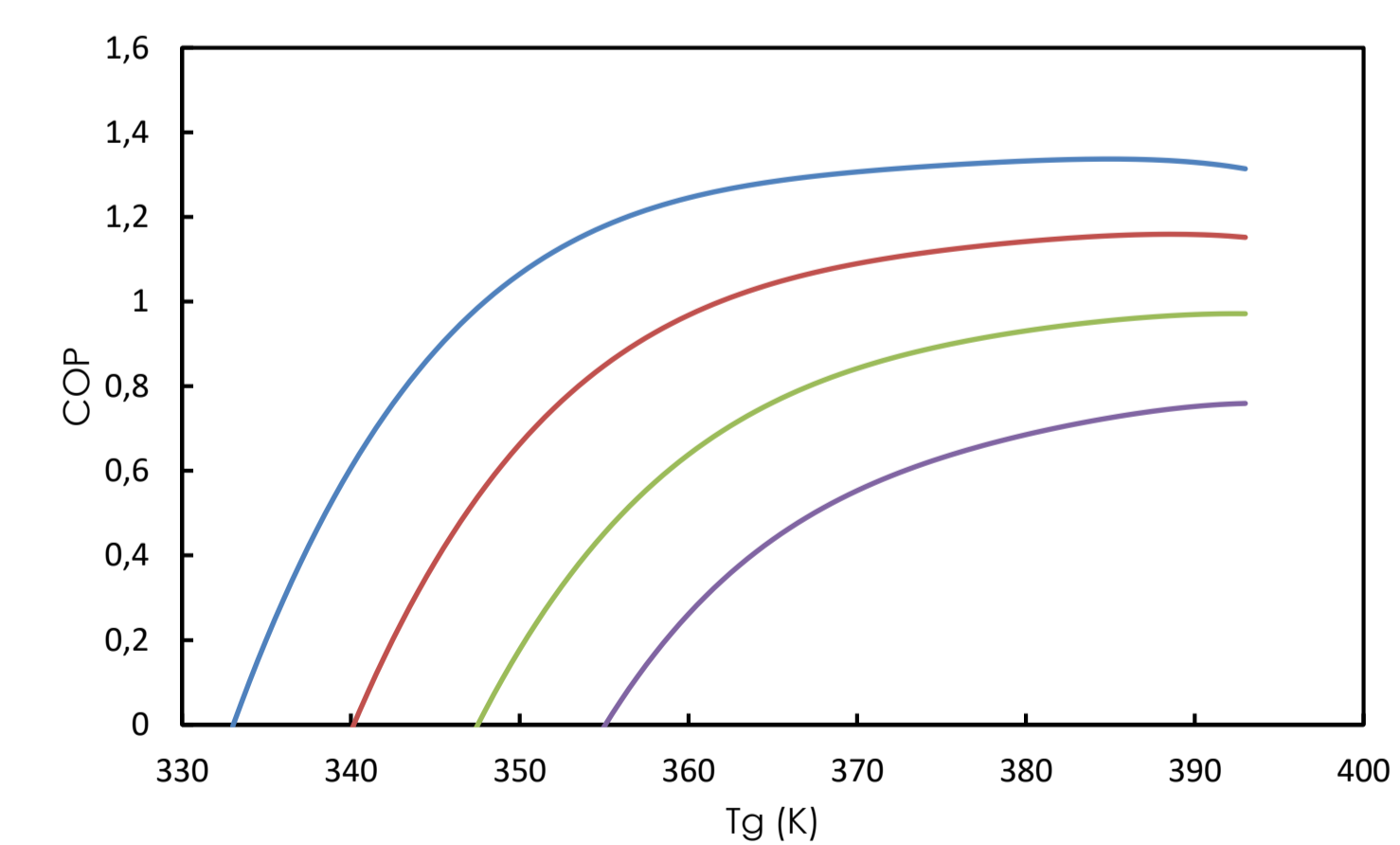


Vapor – Liquid Equilibria



Vapor-liquid equilibria of the {glyceline + CO₂} binary system: — 313.15K, — 323.15K, — 333.15K, — 343.15K, — 353.15K, — 363.15K, — 373.15K, — 383.15K.

Coefficient Of Performance



Coefficient of performance as a function of the temperature of the generator for different pressures at the generator/condenser:
 — 55 bar (T_c = 291.4 K) — 60 bar (T_c = 295.15 K)
 — 65 bar (T_c = 298.61 K) — 70 bar (T_c = 301.9 K)
 Others operating conditions:
 P_{low} = 40 bar, T_e = 278.15K, T_a = 313.15K.

Conclusion

Experimental measurements of {CO₂ + glyceline} binary system were performed in order to evaluate its possible use as a working fluid in a **single-effect absorption chiller**.

In this work, the values of the COP easily higher than 0.7 strengthen the idea that deep eutectic solvent could be a **new alternative** for working mixture in absorption chiller.

References

- [1] E.-S. Abumandour, F. Mutelet, D. Alonso, Are Ionic Liquids Suitable as New Components in Working Mixtures for Absorption Heat Transformers?, Prog. Dev. Ion. Liq. (2017).
- [2] D.Z. Troter, M.Z. Zlatković, D.R. Đokić-Stojanović, S.S. Konstantinović, Z.B. Todorović, Citric acid-based deep eutectic solvents: Physical properties and their use as cosolvents in sulphuric acid-catalysed ethanolysis of oleic acid, Adv. Technol. 5 (2016) 53–65.
- [3] C.-M. Lin, R.B. Leron, A.R. Caparanga, M.-H. Li, Henry's constant of carbon dioxide-aqueous deep eutectic solvent (choline chloride/ethylene glycol, choline chloride/glycerol, choline chloride/malonic acid) systems, J. Chem. Thermodyn. 68 (2014) 216–220.

We would like to acknowledge support from CNRS (France) and TOTAL through the PEPS project

