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Study the Dissociation Enthalpies for R134a Clathrate Hydrate in Binary and Ternary Systems

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Abstract

In the present work the clathrate hydrate dissociation enthalpies of refrigerant R134a+ water system, and R134a + water + salt system were determined. The heat of dissociation of three types of aqueous salts solutions of NaCl, KBr and NaF at three concentrations (0.09, 0.17and 0.26) mol·kg^{-1} for each salt type, were enthalpy measured. The Clapeyron equation was used tocalculate heat of dissociation of experimental data for binary and ternary system.In order to find the effect of compressibility factor on heat dissociation enthalpy, the study was conducted by using equation of state proposed by Peng and Robinson Stryjek-Vera (PRSV). The obtained results of dissociation enthalpy for binary system were (143.8) kJ.mol^{-1} without gas compressibility factor (z) and (136.08) kJ.mol^{-1} with z where the variation between two values was (5.3%). For ternary system (R134a+ water +NaCl) at three concentrations of this salt, the calculated values were in the range of (146.7 - 154.1) kJ.mol^{-1}without z and (138.02-145.14) kJ.mol^{-1}with z where the variation rang between two values was (5.8-5.7) %. The other two types of salts given similar results within (0.886 - 0.129) % deviation rang about NaCl results without z and (0.818-0.149) % deviation rang with z values.

Keywords: *Clathrate, Gas Hydrate, HFC-R134a, Dissociation Enthalpy, Ternary System.*

1. Introduction

Clathrate gas hydrates are ice-like components which the molecules of gas (name guest molecules) such as methane, carbon dioxide, nitrogen, refrigerant gas etc., are occluded in crystalline cells, consisting of water molecules (called cage molecules) retained by the energy of hydrogen bonds as shown in fig. (1). There are three types of gas hydrate structures of sI, sII, and sH would form [1]. In spite of the gas hydrates can cause significant damage to the oil and gas industry due to their formation in numerous hydrocarbon production and processing operations, it has been well studied that they can used in different field, which named "positive" such as food processing, desalination, gas storage, cold storage systems, gas transportation, gas separation and carbon dioxide sequestration. The interest in gas hydrate related to its properties, such large heat of dissociation [2]. Several of Hydro Chloro Fluoro Carbon (HCFC) and Hydro Fluoro Carbon (HFC) refrigerants can form the hydrate in presence of water. Because of proper melting temperature and fair heat transfer coefficients, hydrate of refrigerants has a good condition to use in energy storage at off-peak periods at power industry. R-134a, R-141b and R-152a are the most common HFC and HCFC refrigerants that are used in hydrate researches [3].

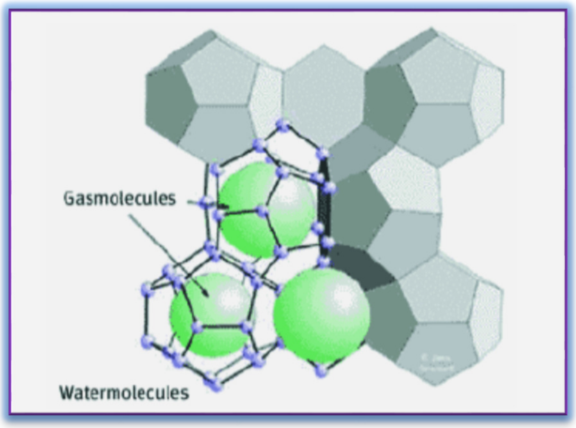

Fig. 1. Structure of gas clathrate hydrate [1].

The dissociation of hydrate crystals is an endothermic process. For such a process to occur, heat of some form must be provided by an external source in order to break the bonds that are present in hydrate structure. It was observed that the dissociation process is analogous to that of the nucleate boiling phenomena [4]. The hydrate dissociation enthalpy is very important because their appearances the ability to use gas hydrate system at different process such as cold gas storage, desalination and gas separation. When the enthalpy dissociation for the system is high, the system can be used with good economic feasibility [5]. There are many literatures that deal with the experimental measurement for clathrate hydrate dissociation conditions ,such as Aimee S. etal.,[6] studied the experimental dissociation conditions of clathrate at different temperature and pressure for ternary system consist of various refrigerant gases (R134a, R410a and R507),water and sucrose aqueous solution at different concentration of succor .And the hydrate dissociation conditions modeling by a thermodynamic relationships that based on the Van der Waals-solid solution theory where, the benefit of the dissociation data obtained is to use in design of aqueous solution separation process .Sarshar M. etal.,[7] developed two correlations from the experimental data that obtained from another researches to calculate the enthalpy of clathrate hydrate dissociation in stat of simple i.e. a single component gas hydrate and mixed gas hydrates depending on the Clausius-Clapeyron equation. Ngema P. etal.,[8] who performed the experimental measurements to conditions of gas hydrates dissociation were undertaken at range of temperatures and pressures , by using binary and ternary system which consist of refrigerant gases as (R134a, R410a, and R507) with salt aqueous solutions for various salt concentrations. Then, modeling of the experimental dissociation data measured by using thermodynamic relationships and compared between two results. Ngema P. etal.,[9] presented the experimental study for the gas clathrate dissociation conditions for systems comprising of different gas refrigerants (R134a, R410a, and R507) , water and calcium chloride at varying salt molarities . The clathrate dissociation conditions that obtained can be used in the design of industrial treatment of waste water and optimization conditions for desalination processes.

2. Measurement Methods of Clathrate Hydrate Dissociation Enthalpy (ΔH_d)

The heat of hydrate dissociation (ΔH_d) can be identified through two methods direct and indirect, in the direct method the calorimetric was used to measure the heat of dissociation. Lin etal.,[10], Martínez etal.,[11] and Delahaye etal.,[12] measured the heat of dissociation for carbon dioxide hydrate by calorimetric method. Dongyoung L. etal.,[13] who measured the experimental values of dissociation enthalpies for binary system pure gas refrigerant R-134a hydrate and the ternary system HFC-134a hydrates in the presence of NaCl by differential scanning calorimeter (DSC) method. To used their obtained data in application of desalination processes.

A second method (indirect) which used to calculate the heat of dissociation (ΔH_d) by applied Clausius- Clapeyron equation for three-phase (liquid water, hydrate, vapour) of hydrate dissociation equilibrium data of hydrate forming systems. This method is the easier and simpler method to estimate the enthalpy of dissociation.

Using the Clausius- Clapeyron equation which is stated below [14]:

$$\frac{d\ln p}{d(1/T)} = \frac{-\Delta H_d}{zR} \qquad \ldots(1)$$

Where: T is temperature, P is the pressure, ΔH_d is the heat of dissociation, R is the universal gas constant and z is the gas compressibility factor.

Khaliket et al., [15] mentioned that the heat of dissociation for carbon dioxide hydrate is calculated by indirect method.In his work, the compressibility factor z, was determined from Pitzer's equation. Furthermore, it was also shown that the presence of electrolytes affects to the dissociation heat (ΔH_d) of the clathrate hydrate.

Hashemi H. et al., [16] declared that the (ΔH_d) of the refrigerant hydrates are a critical property of a cold storage medium, which calculated for refrigerants R404A, R406A, R410A, R507C and R407C at different temperatures by the indirect method in which z is the gas compressibility factor obtained using Peng and Robinson Stryjek-Vera (PRSV) equation of state. Graydon K., [17] calculated the enthalpies of the methane hydrate dissociation by direct analysis using the Clapeyron equation. Khalik M. etal., [18] estimated the dissociation enthalpies of pure CO_2 hydrate and mixed CO_2 and R134a hydrate by indirect measurement using the Clausius–Clapeyron equation. A significant increase was observed for dissociation enthalpies of mixed hydrates at different concentrations of carbon dioxide. Qazi N. etal.,[19] pointed out in his work using of Clausius-Clapeyron equation to determine the dissociation enthalpies of pure CH4 and pure carbon dioxide gas clathrate depending on experimental data at various pressure and temperature. Shicai S. etal., [20] calculated an important thermal parameter in clathrate was the dissociation enthalpies for methane hydrate in various salt solutions by the Clausius-Clapeyron equation. Sabil K. et al [21] calculated the heat of dissociation for carbon dioxide hydrate in the presence of electrolytes by indirect method Clausius–Clapeyron equation. Where, the compressibility factor was determined from Pitzer's equation.

3. Cubic Equation for Compressibility Factor (Z) Calculation

To calculate the compressibility factor (z) by Peng–Robinson equation of state which later modified by Javanmardi et al. **[22]**:

$$P=\frac{RT}{V-b}-\frac{a}{V^2-2bV-b^2} \quad \ldots(2)$$

Peng–Robinson equation which is one of the cubic equation of the state given by **[23]**:

$$Z=\frac{V}{V-b}-\frac{aV}{RT\,(V^2+2bV-b^2)} \quad \ldots(3)$$

Where

$$Z=\frac{PV}{RT} \quad \ldots(4)$$

$$T_r=\frac{T}{T_c} \quad \ldots(5)$$

$$P_r=\frac{P}{P_c} \quad \ldots(6)$$

$$a(T)=0.457235\left(\frac{R^2T_c^2}{P_c}\right)\alpha(T) \quad \ldots(7)$$

$$b=0.077796\left(\frac{RT_c}{P_c}\right) \quad \ldots(8)$$

The expression proposed by Smith H.etal., [24] is used for the α:

$$\alpha(T)=(1+k(1-T_R))^2 \quad \ldots(9)$$

$$k=0.37464+1.54226w-0.26992w^2 \quad \ldots(10)$$

Equation (3) rearranged to give **[25]**:

$$Z_3+\beta Z_2+\gamma Z+\delta=0 \quad \ldots(11)$$

$$A=\frac{aP}{R^2P^2} \quad \ldots(12)$$

$$B=\frac{bP}{RT} \quad \ldots(13)$$

$$\beta=B-1 \quad \ldots(14)$$

$$\gamma=A-3B^2-2B \quad \ldots(15)$$

$$\delta=B^3+B^2-AB \quad \ldots(16)$$

The following two values are first calculated [26]:

$$q=\frac{\beta^2-3\gamma}{9} \quad \ldots(17)$$

$$r=\frac{2\beta^2-9\beta\gamma+27\delta}{54} \quad \ldots(18)$$

$$\theta=\arccos\left(\frac{r}{q^{\frac{3}{2}}}\right) \quad \ldots(19)$$

Then, the three roots are given by:

$$Z_1=-2q^{1/2}\cos\left(\frac{\theta}{3}\right)-\left(\frac{\beta}{3}\right) \quad \ldots(20)$$

$$Z_2=-2q^{1/2}\cos\left(\frac{\theta+2\pi}{3}\right)-\left(\frac{\beta}{3}\right) \quad \ldots(21)$$

$$Z_3=-2q^{1/2}\cos\left(\frac{\theta+4\pi}{3}\right)-\left(\frac{\beta}{3}\right) \quad \ldots(22)$$

In present study, R-134a refrigerant was used in the hydrate formation for binary system (R-134a and water) and ternary system (R-134a, water, salt). Three types of salts NaCl, KBr and NaF at three concentrations (0.09, 0.17 and 0.26) $mol\cdot kg^{-1}$ for each type of salt, were used in ternary system. Enthalpy conditions of dissociation to R-134a refrigerant gas hydrate for binary and ternary systems were measured using a conventional isochoric Pressure search method.

4. Isochoric Pressure Search Method

In the isochoric operation preliminary system temperature and pressure is set in the hydrate instability region, as in fig.(2).At point A ,was the initial point at which the temperature of the cell is lowered and leading the pressure of the cell to decrease to point B. At point B, the gas clathrate begins to form and the pressure immediately decreases further to reach the point C. At this point, the temperature is began increased and also the pressure increase because the hydrate crystals was dissociate. When the clathrate hydrates are dissociated, all the gas is released from the hydrate crystals and the temperature and pressure are recorded as the dissociation conditions. The isochoric method was independent of visual observation and since the process is a closed system, enables to operate at higher pressures [27].

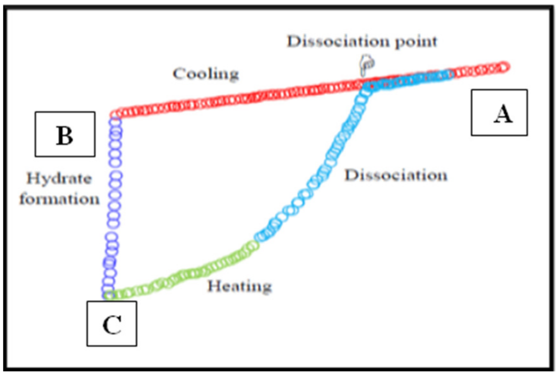

Fig. 2. Isochoric pressure search method [27].

5. Experimental Work

Materials: Table (1) presents the information about the materials which used in the present study.

Table1,
Show the details of different salts, refrigerant and water which are used in this study.

materials	Chemical Formula	Molecular weight (g/mol)	provider	phase
Distilled water	H_2O	18	laboratory	liquid
R134a	CF3CH2F	102.03	Public market	gas
sodium chloride	NaCl	58	Fiuka Germany	solid
Potassium bromide	KBr	119.002	Himedio India	solid
Sodium fluoride	NaF	41.99	Fiuka Germany	solid

Apparatus

Aschematic diagram of the experimental setup is shown in fig. (3). The experimental cell was cylindrical glass with inner and outer diameter (135 and 145) mm respectively, the cell height was 150 mm, the effective volume approximately 1500 cm^3. The cell was equipped with three resistance thermocouples (k-type) located at different levels, the thermocouples connected to interphase type MAX6675 Temp Module Arduino, which in connected to computer to records temperatures for each run. The cell also equipped a mixer type Heidolph RZR 0, there was pressure gaugeconnected to the cell type. Fig. (1) shows the main features of the experimental rig.

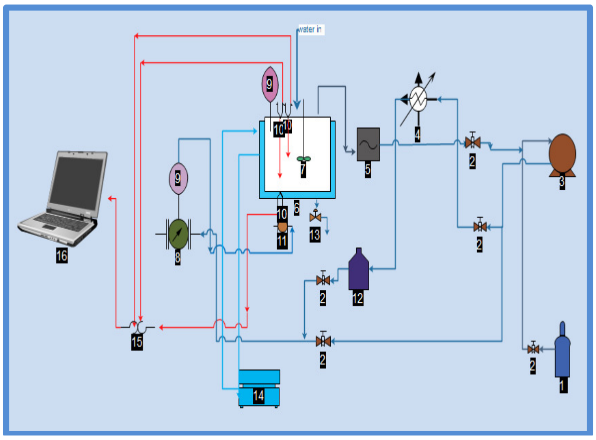

Fig. 3. Schematic flow diagram for the experimental unit: (1) R134a refrigerant cylinder;(2) needle valve;(3) gas compressor;(4) condenser;(5)accumulator ;(6)Experimental cell;(12) gas collection cylinder ;(7)mechanical stirrer; (8)flow meter;(9)pressure gauges;(10) thermocouples(k-type);(11) rotary valve ;(13) drain valve ;(14) chiller;(15)interface system;(16) computer.

Fig. 4. The Apparatus.

Experimental Run

The dissociation conditions of the gas hydrate was at isochoric pressure method. The experiment started by filling the cell with distilled water to clean the cell, then it was evacuated to a pressure of (-0.67) cmHg gauge for of 30 min. About 250 ml pure water or (NaCl, KBr, NaF) aqueous solution at (0.09, 0.17and 0.26) mol.kg^{-1} for each salt charged into the cell. The cell was surrounded by a water jacket which supplied from water circulation bath controlled temperature. The residual air in the cell was evacuated, after that the cell was pressurized with refrigerant gas (R134a) to the desired pressure. And mixer stirred turn on into the cell to ensure homogenous mixing until stabilization of the measured temperature and pressure.Then, the temperature was slowly decreased to facilitate the nucleationof gas hydrates visually. The pressure was decrease gradually with increasing of hydrate formation till reach fixed value. After the formation step, the water bath temperature increased slowly for hydrate dissociation step which causes increased the pressure inside the cell until reach to the initial conditions of pressure and temperature.

Fig.(5) provides an example for clarification the isochoric method for hydrate formation and disassociation curves obtained in this study for the R134a and water system. The region of hydrate formation represented by cooling curve (A) when, it is noted that the temperature readings start decreasing step by step to a certain temperature and a sharp decrease of pressure because of the hydrates formation as a result of the solubility of R134a in water. Then, it stabilizes at constant pressure, after these point the pressure and temperature increased as the dissociation region represented by heating curve (B). The intersection between the cooling (A) and heating (B) curves indicates the equilibrium transition from (hydrate + liquid + gas) to (liquid + gas) and that was called as the hydrate equilibrium point or dissociation point where the pressure and temperature are at equilibrium.

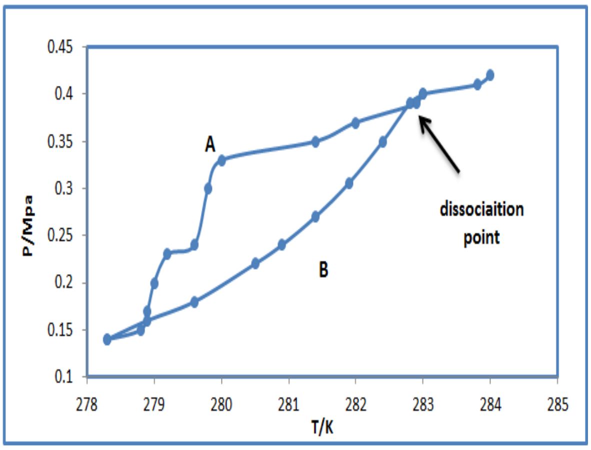

Fig. 5. Pressure vs. temperature equilibrium curves for R134a - water system at hydrates stability conditions.

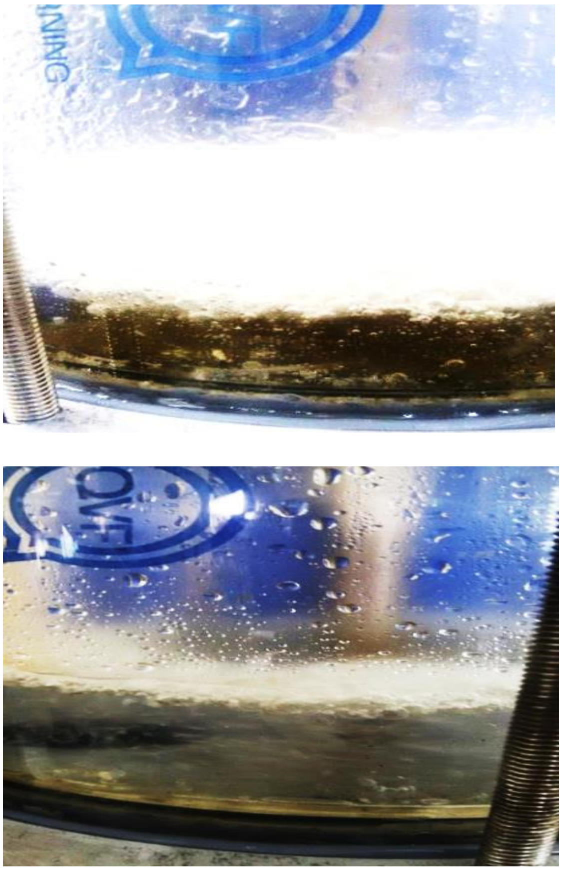

Fig. 6. Hydrate formation and disassociation for the R134a and water system.

6. Results & Discussion

Dissociations Data of R134 Refrigerant Clathrate Hydrate

The dissociation data for [1, 1, 1, 2-tetrafluoroethane (R134a) (1) +water (2)] in this study was measured by the experimental apparatus and compared with literatures. According to the experimental results in fig.(7) was observed equitable amount of scatter when comparing the data of this work to the literatures **[3],[8]** and **[28]** for the same binary system. In a present work the hydrate dissociation pressure is lower than that of literatures [3] and [28] and identical with literature [8]. While the hydrate dissociation temperature of this investigation higher than that of literatures [3] and [28] and approximately Convergent with literature [8]. Because of, those most light molecules such as methane, ethane, propane, normal butane, nitrogen, carbon dioxide and hydrogen sulfide will form the hydrates under specific conditions of high pressure and low temperature. But the use of refrigerants to form gas hydrate enable hydrate formation at near ambient conditions compared to hydrate formation using hydrocarbons [16].

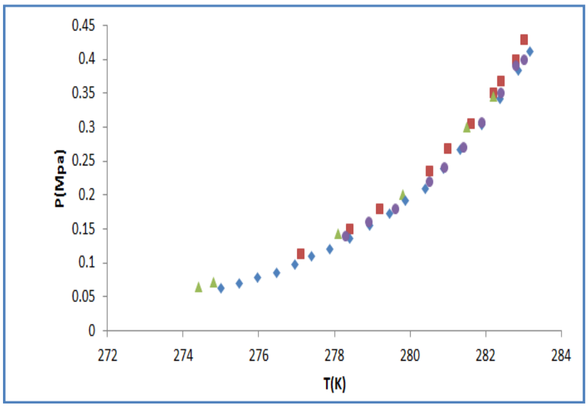

Fig. 7. Experimental data for R134a hydrate dissociation phase diagram: ● this work , ▲ literature [3]; ♦ literature [8]; ■ literature [28]

Ternary system R134a+water dissociation date in presence salt:

The presence of the salt in the refrigerant water system causes depression of water freezing point and inhibition water from vaporizing this is because of the stronger interactions between water and salt. The highest and lowest hydrate dissociation points measured were dependent on the freezing point and vapour depression data [29].

Figs. 8,9,10 show hydrate dissociation for ternary system with three types of salt NaCl, KBr, NaF with three different concentrations for each type of salt (0.09, 0.17 and 0.26) mol·kg^{-1}. Hydrate dissociation conditions were measured for ternary systems to examine effect of the salt concentration on dissociation conditions and stability.

From three figs. (8,9and 10) it is obvious that increasing salt concentration in the aqueous solution , causes to reduce hydrate dissociation temperature that may be explained because of refrigerant R134a solubility decreases with increasing salt concentration as the interactions between the salt ions and water molecules are stronger than the interactions between water and dissolved gas refrigerant R134a.Thetemperature low for hydrate formation reasoned by the particular salt which called hydrate inhibition strength. The hydrate formation temperature is affected by the type of salts presence in the hydrate forming system because the different types of salts have different hydrate inhibition strength [13], [15].In the range of the study, it was founded that NaF salt has relatively the least hydrate inhibition strength while NaCl and KBr salts are the the highest inhibition strength. Therefore, NaF salt solution has increase in the hydrate dissociation temperature compared to the other two solutions of salts as shown in fig. (10). The hydrate inhibition strength on an electrolyte depends on the ionic size. When the ion radius decrease, the bond between the water molecules and the ions becomes stronger since Na$^+$(0.98 Å) has a smaller ionic radius compared to K$^+$ (1.38 Å), therefore Na$^+$ should have a stronger inhibiting effect for hydrate formation [30].

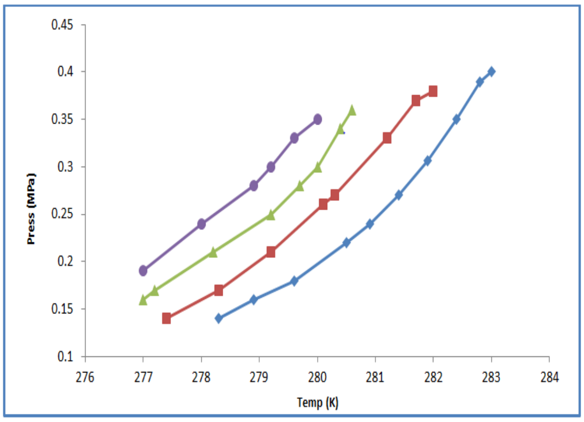

Fig. 8. R134a hydrate dissociation data for the R134a - water - NaCl system this work: ■without salt, ■ 0.09 mol/kg, ▲0.17 mol/kg● 0.26 mol/kg.

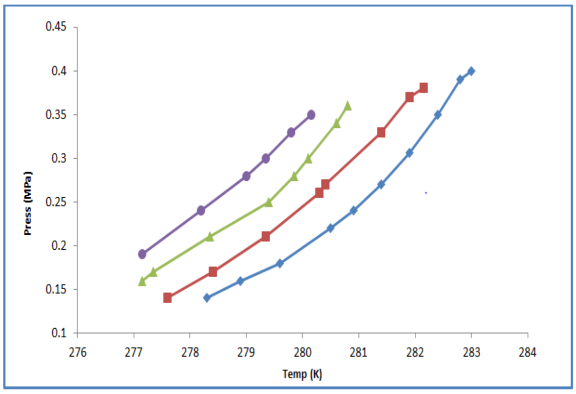

Fig. 9. R134ahydrate dissociation conditions for ternary system with KBr salt of this work: ■inabsence salt, ■ 0.09 mol / kg, ▲0.17mol.kg^{-1}●0.26mol/kg.

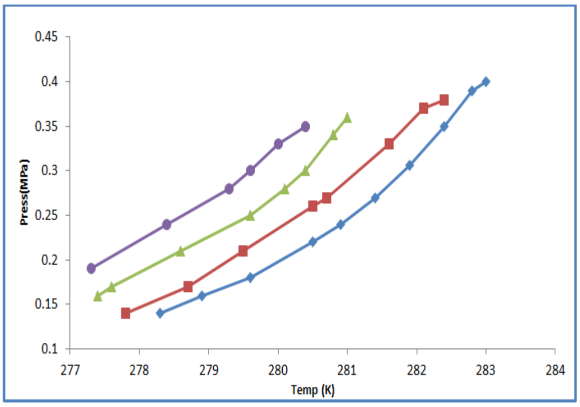

Fig. 10. R134a hydrate dissociation conditions in presence NaFsalt in present studywork: ■ without salt, ■ 0.09 mol/kg· ▲0.17mol/kg●0.26 mol/kg

The plot of Ln P vs. 1/T for dissociation data of the of present work to obtain the heat of dissociation forR134a hydrate was shown in fig.(11).

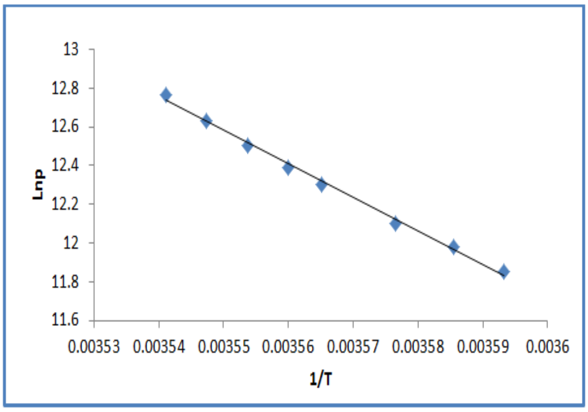

Fig. 11. dissociation data of R134 hydrate, represented by ln P vs. 1/Tplot.

From figs.(11, 12 and 14) can observe the good linear relationships from plot of (lnP) versus (1/T) for hydrate Refrigerant of binary system only and also in presence NaCl and NaF at various concentrations, which show more linear than R134a in presence KBr at different concentration that shown in fig.(13).

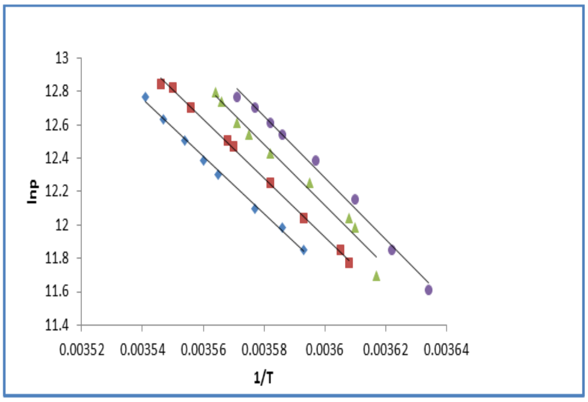

Fig.12. The logarithms of the dissociation pressures (ln P) versus (1/T) along R134a(V)– liquid water (Lw)–hydrate (H) in the presence and absence NaCl coexistence lines♦without salt;■0.09 mol/ kg;▲0.17 mol/kg;●0.26 mol/kg.

In the present study and based on available experimental data for enthalpy of hydrate dissociation when pure water or at presence of sodium chloride shows ions impact on the enthalpy of hydrate dissociation, because at all three concentrations of sodium chloride in the aqueous solution, the enthalpies of dissociation of the gas hydrate are higher than of pure water. However, Khalik B. et al., [15] has found that at 3mol% of sodium chloride the enthalpy of the CO_2 hydrateis higher than that of pure water. That is because the presence of electrolyte in the system requires a higher energy to form hydrate and similarly, a higher energy to dissociate the hydrate formation. Although this agreement may be valid to a high concentration of sodium chloride, it is not valid for an aqueous solution with low concentrations of sodium chloride.

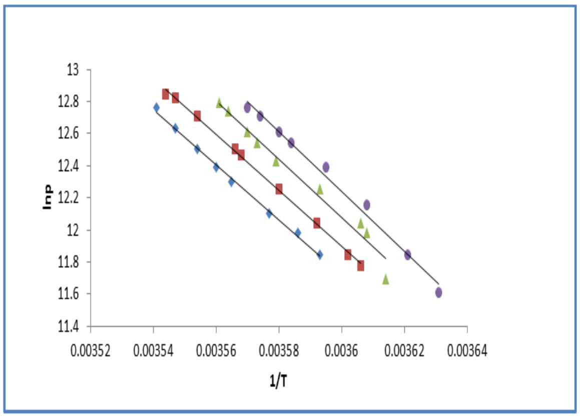

Fig. 13. The logarithms of the dissociation pressures (ln P) versus (1/T) along R134a (V)–water (Lw) –hydrate (H) in the presence and absence KBr coexistence lines♦ no salt; ■ 0.09 mol/kg; ▲0.17 mol/kg; ●0.26 mol/kg.

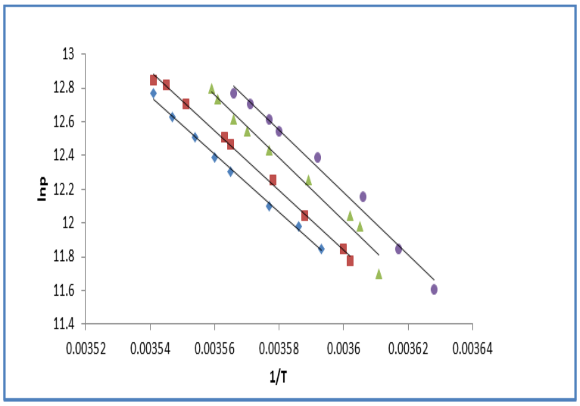

Fig.(14): The logarithms of the dissociation pressures (ln P) versus (1/T) along R134a(V)–water (Lw) –hydrate (H) in the presence and absence NaF coexistence lines♦ without salt; ■ 0.09 mol/kg; ▲0.17 mol/kg;● 0.26mol/kg.

When compare calculated ΔH_d with compressibility factor z and without compressibility factor (see table 2), the obtained ΔH_d with compressibility factor z seems more close to the literature data (see table 3), while ΔH_d without compressibility factor are far away from literature. The different between this study values with other literature as a result of the different equation of state(EOS) used to estimate z. The enthalpy of dissociation of the R134a hydrate at three concentrations of sodium chloride in the aqueous solution is higher than that of pure water in the estimated value. In the present work, the enthalpy of dissociation of R134a in presence two different electrolytes, namely potassium bromide (KBr) and sodium fluoride (NaF) in the aqueous solution increases with increasing concentration of the electrolyte from 0.09 to o.26 mol.kg^{-1}. The table (2) and equation (23) show dissociation heat deviation was about (5-7%), this percentage is important when consider the ability of refrigerant use in cool storage application also, this deviation must be considered for desalination process as heat of dissociation of aqueous salt supplied to the systems (endothermic). Le H. **[28]** suggested that the presence of electrolyte in the system requires a higher energy to form hydrate and similarly, a higher energy to dissociate the hydrate formation. The deviations between the enthalpies with calculate z and without calculate z shown below:

$$\text{Deviation} = \frac{(\Delta H_d)without\ z - (\Delta H_d)with\ z}{(\Delta H_d)without\ z} * 100\% \qquad \ldots(23)$$

Where (ΔH_d) without z is the enthalpy of systems without calculates the compressibility factor z, and the (ΔH_d with z) is the enthalpy of systems depends on the compressibility factor z. It can be seen from Table (2) that the deviationof the enthalpy with z compares with the enthalpy without z in presence and absence different salts at different concentrations.

Table 2,
Enthalpy of dissociation ΔH_d of different systems of R134a refrigerant hydrate for various salts.

system	ΔH_d(KJ/mol)(Ideal)	ΔH_d(KJ/mol) *z(Real)	Deviation%
Water+R134a	143.8	136.08	5.3
Water+R134a+0.09mol/kgNaCl	146.7	138.02	5.9
Water+R134a+0.17mol/kgNaCl	152.6	143.77	5.7
Water+R134a+0.26mol/kgNaCl	154.1	145.14	5.8
Water+R134a+0.09mol/kg KBr	145.4	136.89	5.8
Water+R134a+0.17mol/kg KBr	152.4	143.6	5.7
Water+R134a+0.26mol/kg KBr	154.3	145.35	5.8
Water+R134a+0.09mol/kg NaF	146.7	137.4	6.3
Water+R134a+0.17mol/kg NaF	153.1	144.28	5.7
Water+R134a+0.26mol/kg NaF	153.6	144.72	5.7

Table 3,
Experimental and literature data of the enthalpies of dissociation for R134a+water binary system.

system	ΔH_d(KJ/mol)	literature
R134a+water	136.08	This work
	124.1	Liang et al,[31]
	124.1	Mohammadi et al., [32]
	143.48	Casandra [33]

7. Conclusion

1. The hydrate dissociation conditions were reported for binary system; R134a+water and ternary system; R134a+water+salt for three types of salt at three concentrations (0.09, 0.17and 0.26) mol.kg^{-1}.
2. The isochoric method was applied to measurement the conditions of hydrate dissociations in the binary and the ternary systems.
3. The presence of NaCl, KBr and NaF salts in the gas hydrate system reason shifted the dissociation temperatures of refrigerant hydrate to lower values.
4. The heats of dissociation for R134a clathrate were determined by the indirect method (Clapeyron equation) depended on the measured dissociation data for binary system and also in presence different salts for various concentrations.
5. **5.** From ΔH_d results that were obtained for R134a hydrate system, may note that heat of dissociation with high accuracy by Clapeyron equation include compressibility factor Z that obtained by relationship of Peng Robinson from the results that obtained for ΔH_d without compressibility factor.

Notation

T_r	reduced temperature
P_r	reduced pressure
R	gas constant
V	molar volume
T_c	critical temperature
P_c	critical pressure
ω	acentric factor

8. References

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دراسة المحتوى الحراري لتفكك الكلاثريت (لغاز التبريدR134a الرطب) بالنظامين الثنائي والثلاثي

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الخلاصة

في هذا البحث تم حساب حرارة التفكك للنظام الثنائي المتكون من (غازالتبريدR134a+ماء) والنظام الثلاثي المتكون من (غازالتبريد R134a +ماء + ملح). حيث تم حساب حرارة التفكك لثلاثة أنواع من محاليل الأملاح هي كلوريد الصوديوم، بروميد البوتاسيوم وفلوريد الصوديوم عند ثلاثة تراكيز(٠,٠٩، ٠,١٧، ٠,٢٦) مول\كغم. معادلة كلابيرون استخدمت لحساب حرارة التفكك للنظام الثنائي والثلاثي اعتمادا على البيانات العملية للتفكك. وحصيلة الدراسة تمت باستخدام معادلة الحالة لـ (Peng and Robinson) لأيجاد تأثير معامل انضغاط الغاز (z) على حرارة التفكك. وكان ناتج النظام الثنائي هو(١٤٣,٨) كجول\مول بدون z وبوجود z (١٣٦,٠٨) كجول \مول علما أن الانحراف بين القيمتين هو(٥,٣) %. معدل القيم المحسوبة للنظام الثلاثي بوجود كلوريد الصوديوم عند التراكيز الثلاثة للملح من دون z بالمدى (١٥٤,١-١٤٦,٧) كجول \مول ومع z (١٣٨,٠٢-١٤٥,١٤) كجول \مول وكان معدل الانحراف بين القيمتين هو (٨، ٥ - ٧، ٥) %. النوعان الآخران من الاملاح لهما نتائج مشابهة لنتائج ملح كلوريد الصوديوم بمعدل انحراف (٠,٨٨٦- ٠,١٢٩)% بدون z ومعدل انحراف (٠,١٤٩-٠,٨١٨) % عند أدخال قيم معامل الانضغاط (z).
