

Vapour Absorption Refrigeration Systems

Nagendra M
CBM Engineer,
Hindusthan Zink .Ltd

The objectives of this lesson are to:

1. Introduce vapour absorption refrigeration systems.
2. Explain the basic principle of a vapour absorption refrigeration system.
3. Compare vapour compression refrigeration systems with continuous vapour absorption refrigeration systems.
4. Obtain expression for maximum COP of ideal absorption refrigeration system.
5. Discuss properties of ideal and real refrigerant-absorbent mixtures.
6. Describe a single stage vapour absorption refrigeration system with solution heat exchanger.
7. Discuss the desirable properties of refrigerant-absorbent pairs for vapour absorption refrigeration systems and list the commonly used working fluids.

1.1. Introduction

Vapour Absorption Refrigeration Systems (VARs) have a place with the class of vapour cycles like vapour pressure refrigeration systems. Notwithstanding, dissimilar to vapour pressure refrigeration systems, the obliged data to absorption systems is as heat. Henceforth these systems are likewise called as heat worked or warm energy driven systems. Since routine absorption systems use liquids for absorption of refrigerant, these are likewise now and then called as wet absorption systems. Like vapour pressure refrigeration systems, vapour absorption refrigeration systems have additionally been marketed and are generally used in different refrigeration and aerating and cooling applications.

Since these systems run on poor quality warm energy, they are favoured when second rate energy, for example, waste heat or sun oriented energy is accessible. Since customary absorption systems use characteristic refrigerants, for example, water or smelling salts they are environment benevolent. In this lesson, the fundamental working rule of absorption systems, the greatest COP of ideal absorption refrigeration systems, basic properties of mixtures and basic absorption refrigeration systems will be discussed.

1.2. Basic principle of a Vapour Absorption Refrigeration System

At the point when a solute, for example, lithium bromide salt is broken up in a solvent, for example, water, the breaking point of the solvent (water) is raised. On the other hand, if the temperature of the solution (solvent + solute) is held steady, then the impact of dissolving the solute is to decrease the vapour weight of the solvent beneath that of the immersion weight of pure solvent at that temperature. In the event that the solute itself has some vapour weight (i.e., volatile solute) then the aggregate weight applied over the solution is the whole of the partial pressures of solute and solvent.

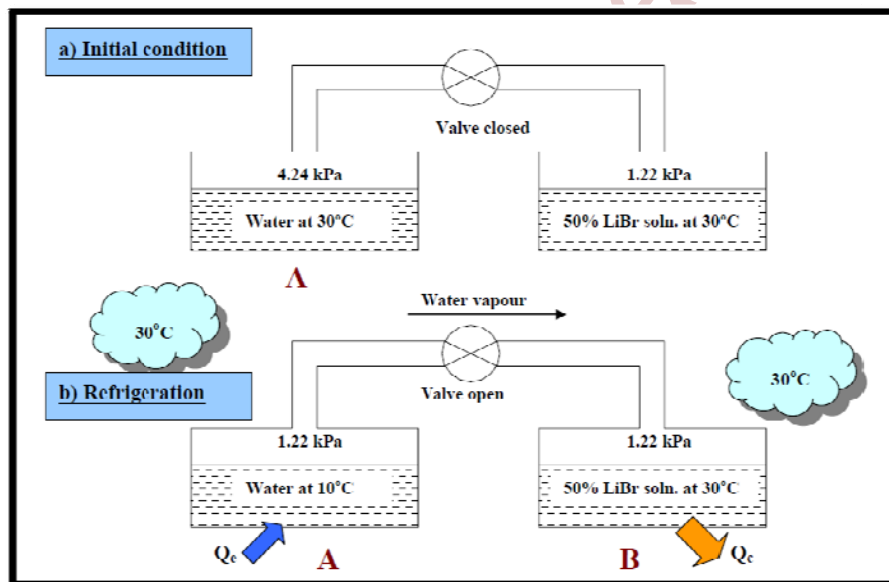
If the solute is non volatile (e.g. lithium bromide salt) or if the breaking point distinction between the solution and solvent is vast ($\geq 300^{\circ}\text{C}$), then the aggregate weight applied over the solution will be practically equivalent to the vapour weight of the solvent just. In the least complex absorption refrigeration system, refrigeration is acquired by associating two vessels, with one vessel containing pure solvent and the other containing a solution. Since the weight is very nearly break even with in both the vessels at balance, the temperature of the solution will be higher than that of the pure solvent.

This implies that if the solution is at ambient temperature, then the pure solvent will be at a temperature lower than the ambient. Henceforth refrigeration impact is delivered at the vessel containing pure solvent because of this temperature contrast. The solvent dissipates because of heat exchange from the surroundings, streams to the vessel containing solution and is consumed by the solution. This procedure is proceeded the length of the organization and temperature of the solution are kept up and fluid solvent is accessible in the holder. For instance, Fig.1.1 demonstrates a game plan, which comprises of two vessels A and B associated with one another through an interfacing funnel and a valve.

Vessel A is loaded with pure water, while vessel B is loaded with a solution containing on mass premise 50 percent of water and 50 percent lithium bromide (LiBr salt). At first the valve uniting these two vessels is shut, and both vessels are at thermal balance with the surroundings, which is at 30°C . At 30°C , the immersion weight of water is 4.24 kPa, and the balance vapour weight of water-lithium bromide solution (50: 50 by mass) at 30°C is 1.22 kPa.

In this manner at initial equilibrium condition, the weight in vessel A is 4.24 kPa, while it is 1.22 kPa in vessel B. Presently the valve between vessels A

and B is opened. Initially because of weight contrast water vapour will spill out of vessel A to vessel B, and this vapour will be consumed by the solution in vessel B. Since absorption for this situation is exothermic, heat will be discharged in vessel B. Presently assume by a few methods the fixation and temperature of vessel B are kept up steady at 50 % and 30 °C, individually. Then at equilibrium, the weight in the whole system (vessels A and B) will be 1.22 kPa (equilibrium weight of 50 % LiBr solution at 30 °C).



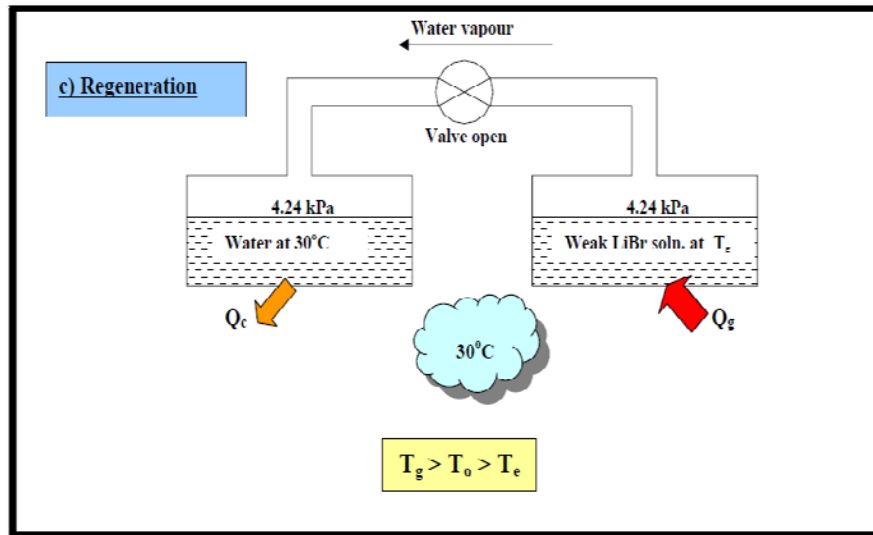


Fig.1.1: Basic principle of vapour absorption systems

The temperature of water in vessel A will be the immersion temperature comparing to 1.22 kPa, which is equivalent to around 10 °C, as demonstrated in the figure. Since the water temperature in A is lower than the surroundings, a refrigeration impact (Q_e) can be delivered by transferring heat from the surroundings to water at 10 °C. Because of this heat exchange, water vaporizes in A, streams to B and is consumed by the solution in B. The exothermic heat of absorption (Q_a) is rejected to the surroundings. Presently for the above methodology to proceed there ought to dependably be pure water in vessel A and vessel B must be kept up dependably at 50 percent focus and 30 °C.

This is unrealistic in a shut system, for example, the one demonstrated in Fig.1.1. In a system with limited estimated stores, gradually the measure of water in A declines and the solution in B gets to be weakened with water. Subsequently, the system weight and temperature of water in an increment with time. Subsequently the refrigeration impact at vessel A reduces gradually because of the lessened temperature contrast between the surroundings and water. Subsequently refrigeration delivered by systems utilizing just two vessels is irregular in nature. In these systems, after a period, the refrigeration procedure must be halted and both the vessels A and B must be taken back to their unique condition.

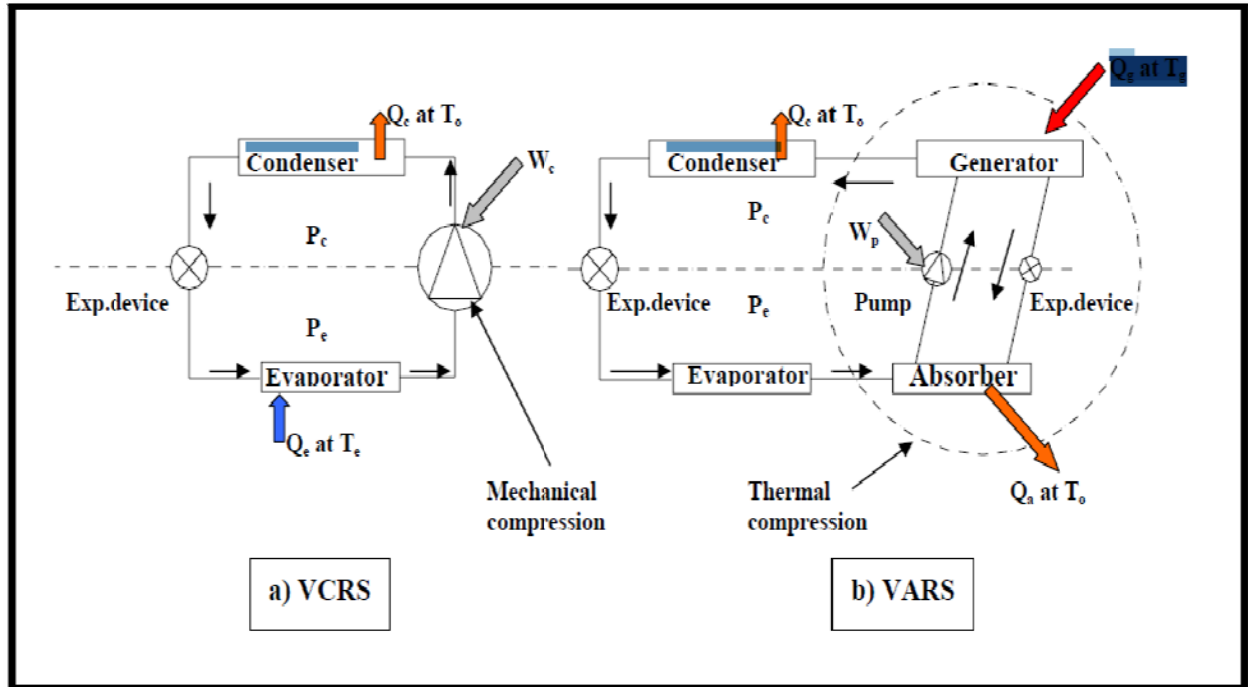
This obliges evacuation of water retained in vessel B and adding it back to vessel A in fluid structure, i.e., a procedure of recovery as indicated in

Fig.1.1(c). Accept that before recovery is completed, the valve in the middle of A and B is shut and both A and B are acquired thermal equilibrium with the surroundings ($30\text{ }^{\circ}\text{C}$), then amid the recovery procedure, heat at high temperature T_g is supplied to the weakened LiBr solution in B, subsequently water vapour is created in B. The vapour created in B is dense into pure water in A by dismissing heat of build up to the surroundings. This methodology must be proceeded till all the water consumed amid the refrigeration prepare (1.1(b)) is exchanged back to vessel A.

Then to take the system back to its unique condition, the valve must be shut and solution in vessel B must be cooled to $30\text{ }^{\circ}\text{C}$. On the off chance that we expect an unfaltering stream methodology of recovery and disregard temperature distinction for heat exchange, then the temperature of water in A will be $30\text{ }^{\circ}\text{C}$ and weight inside the system will be 4.24 kPa . Then the temperature in vessel B, T_g relies on upon the centralization of solution in B. The measure of heat exchanged amid refrigeration and recovery relies on upon the properties of solution and the working conditions.

It can be seen that the yield from this system is the refrigeration acquired Q_e and the information is heat supplied to vessel B amid vapour recovery process, Q_g . The system depicted may be called as an Intermittent Absorption Refrigeration System. The solvent is the refrigerant and the solute is called as spongy. These straight forward systems can be used to give refrigeration utilizing renewable energy, for example, sunlight based energy in remote and country territories. As effectively clarified, these systems gave refrigeration discontinuously, if sun based energy is used for recovering the refrigerant, then recovery procedure can be done amid the day and refrigeration can be created amid the night.

In spite of the fact that the irregular absorption refrigeration systems talked about above are basic in configuration and reasonable, they are not useful in applications that require constant refrigeration. Consistent refrigeration can be acquired by having an altered system with two sets of vessels A and B and additional expansion valves and a solution pump.



Figs.1.2: a) Vapour compression refrigeration system (VCRS)
 b) Vapour Absorption Refrigeration System (VARs)

Figure 1.2(a) and (b) show a continuous output vapour compression refrigeration system and a continuous output vapour absorption refrigeration system. As shown in the figure in a continuous absorption system, low temperature and low pressure refrigerant with low quality enters the evaporator and vaporizes by delivering useful refrigeration Q_e . From the evaporator, the low temperature, low pressure refrigerant vapour enters the safeguard where it interacts with a solution that is weak in refrigerant. The weak solution absorbs the refrigerant and gets to be solid in refrigerant. The heat of absorption is rejected to the outside heat sink at T_o .

The solution that is presently rich in refrigerant is pumped to high pressure utilizing a solution pump and encouraged to the generator. In the generator heat at high temperature T_g is supplied, subsequently refrigerant vapour is generated at high pressure. This high pressure vapour is then consolidated in the condenser by dismissing heat of condensation to the outer heat sink at T_o . The dense refrigerant liquid is then throttled in the expansion gadget and is then encouraged to the evaporator to finish the refrigerant cycle. On the solution side, the hot, high-pressure solution that is weak in refrigerant is

throttled to the safeguard pressure in the solution expansion valve and nourished to the safeguard where it interacts with the refrigerant vapour from evaporator.

Along these lines continuous refrigeration is delivered at evaporator, while heat at high temperature is continuously supplied to the generator. Heat dismissal to the outer heat sink happens at safeguard and condenser. A little measure of mechanical energy is obliged to run the solution pump. On the off chance that we disregard pressure drops, then the absorption system operates between the condenser and evaporator pressures. Pressure in safeguard is same as the pressure in evaporator and pressure in generator is same as the pressure in condenser. It can be seen from Fig.1.2, that the extent that the condenser, expansion valve and evaporators are concerned both pressure and absorption systems are indistinguishable.

On the other hand, the difference lies in the way the refrigerant is packed to condenser pressure. In vapour pressure refrigeration systems the vapour is compacted mechanically utilizing the compressor, where as in absorption system the vapour is initially changed over into a liquid and after that the liquid is pumped to condenser pressure utilizing the solution pump. Since for the same pressure difference, work info needed to pump a liquid (solution) is substantially less than the work needed for packing a vapour because of little specific volume of liquid, the mechanical energy needed to operate vapour absorption refrigeration system is a great deal not as much as that needed to operate a pressure system.

Then again, the absorption system obliges a relatively substantial measure of low-review thermal energy at generator temperature to generate refrigerant vapour from the solution in generator. In this manner while the energy information is as mechanical energy in vapour pressure refrigeration systems, it is mostly as thermal energy in the event of absorption systems. The solution pump work is often unimportant contrasted with the generator heat data. Consequently the COPs for pressure and absorption systems are given by:

$$\text{COP}_{\text{VCRS}} = \frac{Q_e}{W_c}$$

$$\text{COP}_{\text{VARS}} = \frac{Q_e}{Q_g + W_p} \approx \frac{Q_e}{Q_g}$$

Thus absorption systems are advantageous where a large quantity of low-grade thermal energy is available freely at required temperature. However, it will be seen that for the refrigeration and heat rejection temperatures, the COP of vapour compression refrigeration system will be much higher than the COP of an absorption system as a high grade mechanical energy is used in the former, while a low-grade thermal energy is used in the latter. However, comparing these systems based on COPs is not fully justified, as mechanical energy is more expensive than thermal energy. Hence, sometimes the second law (or exeric) efficiency is used to compare different refrigeration systems. It is seen that the second law (or exeric) efficiency of absorption system is of the same order as that of a compression system.

1.3. Maximum COP of ideal absorption refrigeration system

In case of a single stage compression refrigeration system operating between constant evaporator and condenser temperatures, the maximum possible COP is given by Carnot COP:

$$\text{COP}_{\text{Carnot}} = \frac{T_e}{T_c - T_e}$$

If we assume that heat rejection at the absorber and condenser takes place at same external heat sink temperature T_o , then a vapour absorption refrigeration system operates between three temperature levels, T_g , T_o and T_e . The maximum possible COP of a refrigeration system operating between three temperature levels can be obtained by applying first and second laws of thermodynamics to the system. Figure 1.3 shows the various energy transfers and the corresponding temperatures in an absorption refrigeration system.

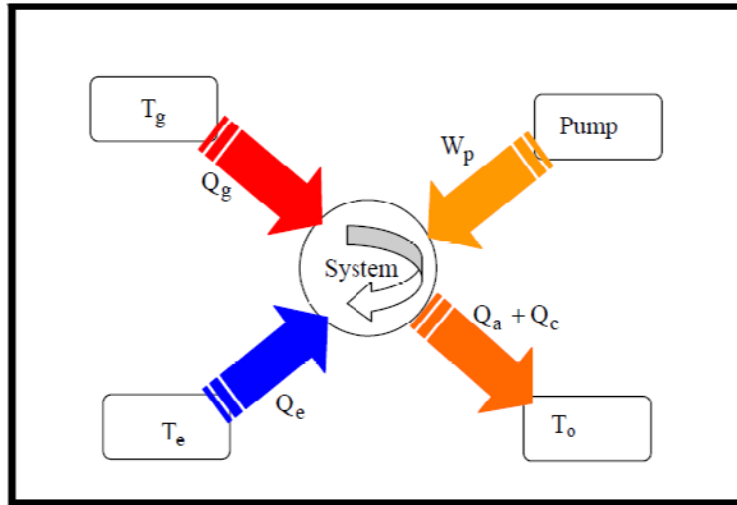


Fig.1.3: Various energy transfers in a vapour absorption refrigeration system

From first law of thermodynamics,

$$Q_e + Q_g - Q_{a+c} + W_p = 0$$

where Q_e is the heat transferred to the absorption system at evaporator temperature T_e , Q_g is the heat transferred to the generator of the absorption system at temperature T_g , Q_{a+c} is the heat transferred from the absorber and condenser of the absorption system at temperature T_o and W_p is the work input to the solution pump.

From second law of thermodynamics,

$$\Delta S_{total} = \Delta S_{sys} + \Delta S_{surr} \geq 0$$

where ΔS_{total} is the total entropy change which is equal to the sum of entropy change of the system ΔS_{sys} and entropy change of the surroundings ΔS_{surr} . Since the refrigeration system operates in a closed cycle, the entropy change of the working fluid of the system undergoing the cycle is zero, i.e., $\Delta S_{sys} = 0$. The entropy change of the surroundings is given by:

$$\Delta S_{surr} = -\frac{Q_e}{T_e} - \frac{Q_g}{T_g} + \frac{Q_{a+c}}{T_o} \geq 0$$

Substituting the expression for first law of thermodynamics in the above equation

$$Q_g \left(\frac{T_g - T_o}{T_g} \right) \geq Q_e \left(\frac{T_o - T_e}{T_e} \right) - W_p$$

Neglecting solution pump work, W_p ; the COP of VARS is given by:

$$COP_{VARS} = \frac{Q_e}{Q_g} \leq \left(\frac{T_e}{T_o - T_e} \right) \left(\frac{T_g - T_o}{T_g} \right)$$

An ideal vapour absorption refrigeration system is totally reversible (i.e., both internally and externally reversible). For a completely reversible system the total entropy change (system+ surroundings) is zero according to second law, hence for an ideal VARS $\Delta S_{total,rev} = 0 \Rightarrow \Delta S_{surr,rev} = 0$. Hence:

$$\Delta S_{surr,rev} = -\frac{Q_e}{T_e} - \frac{Q_g}{T_g} + \frac{Q_{a+c}}{T_o} = 0$$

Hence combining first and second laws and neglecting pump work, the maximum possible COP of an ideal VARS system is given by:

$$COP_{ideal\ VARS} = \frac{Q_e}{Q_g} = \left(\frac{T_e}{T_o - T_e} \right) \left(\frac{T_g - T_o}{T_g} \right)$$

Thus the ideal COP is only a function of operating temperatures similar to Carnot system. It can be seen from the above expression that the ideal COP of VARS system is equal to the product of efficiency of a Carnot heat engine operating between T_g and T_o and COP of a Carnot refrigeration system operating between T_o and T_e , i.e.,

$$COP_{ideal\ VARS} = \frac{Q_e}{Q_g} = \left(\frac{T_e}{T_o - T_e} \right) \left(\frac{T_g - T_o}{T_g} \right) = COP_{Carnot} \cdot \eta_{Carnot}$$

Thus an ideal vapour absorption refrigeration system can be considered to be a combined system consisting of a Carnot heat engine and a Carnot refrigerator as shown in Fig.1.4. Thus the COP of an ideal VARS increases as generator temperature (T_g) and evaporator temperature (T_e) increase and heat rejection temperature (T_o) decreases. However, the COP of actual VARS will be much less than that of an ideal VARS due to various internal and external irreversibility's present in actual systems.

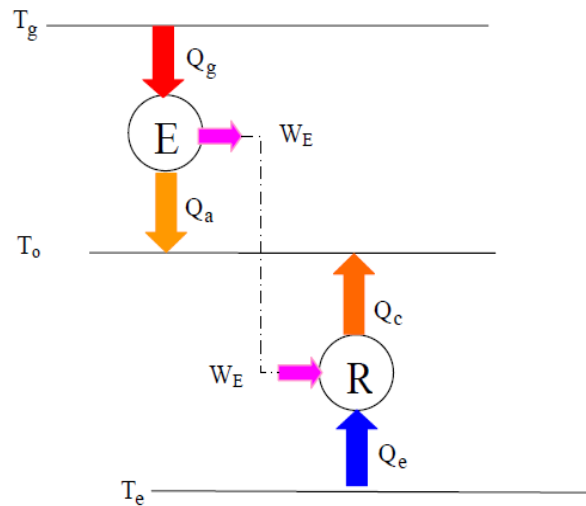


Fig.1.4: Vapour absorption refrigeration system as a combination of a heat engine and a refrigerator

1.4. Properties of refrigerant-absorbent mixtures

The solution used in absorption refrigeration systems may be considered as a homogeneous binary mixture of refrigerant and absorbent. Depending upon the boiling point difference between refrigerant and absorbent and the operating temperatures, one may encounter a pure refrigerant vapour or a mixture of refrigerant and absorbent vapour in generator of the absorption system. Unlike pure substances, the thermodynamic state of a binary mixture (in liquid or vapour phase) cannot be fixed by pressure and temperature alone. According to Gibbs' phase rule, one more parameter in addition to temperature and pressure is required to completely fix the thermodynamic state.

Generally, the composition of the mixture is taken as the third independent parameter. The composition of a mixture can be expressed either in mass fraction or in mole fraction. The mass fraction of components 1 and 2 in a binary mixture are given by:

$$\xi_1 = \frac{m_1}{m_1 + m_2}; \quad \xi_2 = \frac{m_2}{m_1 + m_2}$$

where m_1 and m_2 are the mass of components 1 and 2, respectively

The mole fraction of components 1 and 2 in a binary mixture are given by:

$$x_1 = \frac{n_1}{n_1 + n_2}; \quad x_2 = \frac{n_2}{n_1 + n_2}$$

where n_1 and n_2 are the number of moles of components 1 and 2, respectively. An important property of a mixture is its miscibility. A mixture is said to be completely miscible if a homogeneous mixture can be formed through any arbitrary range of concentration values. Miscibility of mixtures is influenced by the temperature at which they are mixed. Some mixtures are miscible under certain conditions and immiscible at other conditions. The refrigerant-absorbent mixtures used in absorption refrigeration systems must be completely miscible under all conditions both in liquid and vapour phases.

1.4.1. Ideal, homogeneous binary mixtures

A binary mixture of components 1 and 2 is called as an ideal mixture, when it satisfies the following conditions.

Condition 1: The volume of the mixture is equal to the sum of the volumes of its constituents, i.e., upon mixing there is neither contraction nor expansion. Thus the specific volume of the mixture, v is given by:

$$v = \xi_1 \cdot v_1 + \xi_2 \cdot v_2$$

where ξ_1 and ξ_2 are the mass fractions of components 1 and 2. For a binary mixture,

ξ_1 and ξ_2 are related by:

$$\xi_1 + \xi_2 = 1 \Rightarrow \xi_2 = 1 - \xi_1$$

Condition 2: Neither heat is generated nor absorbed upon mixing, i.e., the heat of solution is zero. Then the specific enthalpy of the mixture, h is given by:

$$h = \xi_1 \cdot h_1 + \xi_2 \cdot h_2 = \xi_1 \cdot h_1 + (1 - \xi_1) h_2$$

Condition 3: The mixture obeys Raoult's law in liquid phase, i.e., the vapour pressure exerted by components 1 and 2 ($P_{v,1}$ and $P_{v,2}$) at a temperature T are given by:

$$P_{v,1} = x_1 \cdot P_{1,sat}$$

$$P_{v,2} = x_2 \cdot P_{2,sat}$$

where x_1 and x_2 are the mole fractions of components 1 and 2 in solution, and $P_{1,sat}$ and $P_{2,sat}$ are the saturation pressures of pure components 1 and 2 at temperature T .

The mole fractions x_1 and x_2 are related by:

$$x_1 + x_2 = 1 \Rightarrow x_2 = 1 - x_1$$

Condition 4: The mixture obeys Dalton's law in vapour phase; i.e., the vapour pressure exerted by components 1 and 2 ($P_{v,1}$ and $P_{v,2}$) in vapour phase at a temperature T are given by:

$$P_{v,1} = y_1.P_{total}$$

$$P_{v,2} = y_2 .P_{total}$$

where y_1 and y_2 are the vapour phase mole fractions of components 1 and 2 and P_{total} is the total pressure exerted at temperature T . The vapour phase mole fractions y_1 and y_2 are related by:

$$y_1 + y_2 = 1 \Rightarrow y_2 = 1 - y_1$$

and the total pressure P_{total} is given by:

$$P_{total} = P_{v,1} + P_{v,2}$$

If one of the components, say component 2 is non-volatile compared to component 1 (e.g. component 1 is water and component 2 is lithium bromide salt), then $y_1 \approx 1$ and $y_2 \approx 0$, $P_{v,2} \approx 0$, then from Raoult's and to Dalton's laws:

$$P_{total} \approx P_{v,1} = x_1.P_{1,sat}$$

1.4.2. Real mixtures

Real mixtures deviate from ideal mixtures since:

1. A real solution either contracts or expands upon mixing, i.e.,

$$v \neq \xi_1.v_1 + \xi_2.v_2$$

2. Either heat is evolved (exothermic) or heat is absorbed upon mixing;

$$h = \xi_1.h_1 + (1 - \xi_1)h_2 + \Delta h_{mix}$$

where Δh_{mix} is the heat of mixing, which is taken as negative when heat is evolved and positive when heat is absorbed. The above two differences between ideal and real mixtures can be attributed to the deviation of real mixtures from Raoult's law. Real mixtures approach ideal mixtures as the mole fraction of the component contributing to vapour pressure approaches unity, i.e., for very dilute solutions. Figure 1.5 shows the equilibrium pressure variation with liquid phase mole fraction (x) of ideal and real binary mixtures with positive (+ve) and negative deviations (-ve) from Raoult's law at a constant temperature. It can be seen that when the deviation from Raoult's law is positive (+ve), the equilibrium vapour pressure will be higher than that predicted by Raoult's law, consequently at a given pressure and composition.

The equilibrium temperature of solution will be lower than that predicted by Raoult's law. The converse is true for solutions with -ve deviation from Raoult's law, i.e., the equilibrium temperature at a given pressure and composition will be higher than that predicted by Raoult's law for solution with negative deviation. This behaviour can also be shown on specific enthalpy-composition diagram as shown in Fig. 14.6 for a solution with negative deviation from Raoult's law. Refrigerant-absorbent mixtures used in vapour absorption refrigeration systems; exhibit a negative deviation from Raoult's law, i.e., the process of absorption is exothermic with a negative heat of mixing.

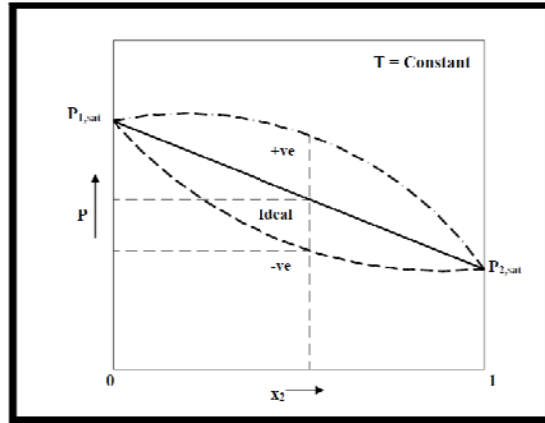


Fig.1.5: Pressure-concentration behaviour of ideal and real mixtures at a constant Temperature

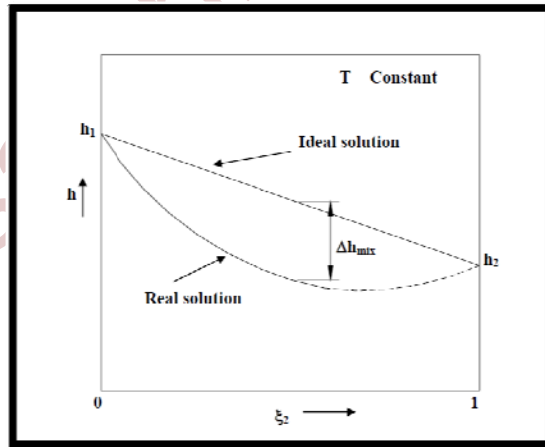


Fig.1.6: Enthalpy-concentration behaviour of an ideal mixture and a real mixture with Negative deviation from Raoult's law

1.5. Basic Vapour Absorption Refrigeration System

Figure 1.7 shows a basic vapour absorption refrigeration system with a solution heat exchanger on a pressure vs temperature diagram. As shown in the

figure, low temperature and low pressure refrigerant vapour from evaporator at state 1 enters the absorber and is absorbed by solution weak in refrigerant (state 8). The heat of absorption (Q_a) is rejected to an external heat sink at T^∞ . The solution, rich in refrigerant (state 2) is pumped to the generator pressure (P_g) by the solution pump (state 3). The pressurized solution gets heated up sensibly as it flows through the solution heat exchanger by extracting heat from hot solution coming from generator (state 4). Heat is supplied to this solution from an external heat source in the generator (Q_g at T_g), as a result refrigerant vapour is generated (absorbent may also boil to give off vapour in case of ammonia-water systems) at state 5.

This high-pressure refrigerant vapour condenses in the condenser by rejecting heat of condensation to the external heat sink (Q_c at T^∞) and leaves the condenser as a high pressure liquid (state 9). This high pressure refrigerant liquid is throttled in the expansion device to evaporator pressure P_e (state 10) from where it enters the evaporator, extracts heat from low temperature heat source (Q_e at T_e) and leaves the evaporator as vapour at state 1, completing a cycle. The hot solution that is weak in refrigerant (state 6) leaves the generator at high temperature and is cooled sensibly by rejecting heat to the solution going to the generator in the solution heat exchanger (state 7). Then it is throttled to the evaporator pressure in the throttle valve (state 8), from where it enters the absorber to complete the cycle.

It can be seen that though not an essential component, the solution heat exchanger is used in practical systems to improve the COP by reducing the heat input in the generator. A solution heat exchanger as shown in Fig.1.7 is a counter flow heat exchanger in which the hot solution coming from the generator comes in thermal contact with the cold solution going to the generator. As a result of this heat exchange, less heat input is required in the generator and less heat is rejected in the absorber, thus improving the system performance significantly.

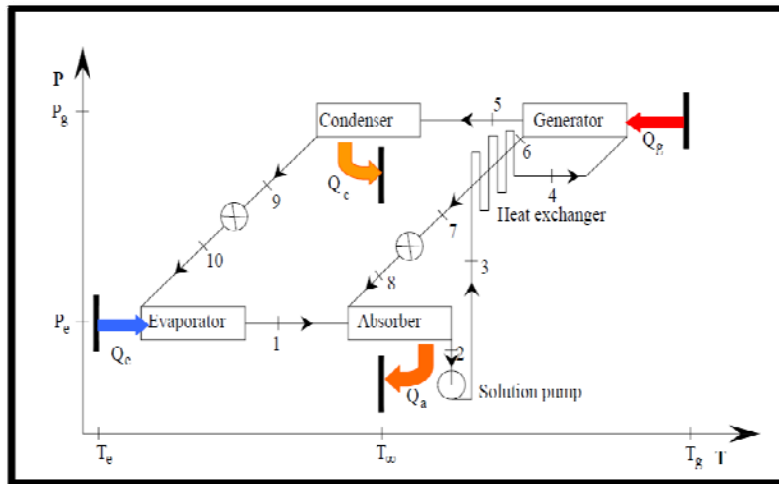


Fig.1.7: Basic vapour absorption refrigeration system with a solution heat exchanger on a Pressure vs temperature diagram

The thermodynamic performance of the above system can be evaluated by applying mass and energy balance to each component assuming a steady flow process. In simple theoretical analyses, internal irreversibility's such as pressure drops between the components are generally neglected. To find the performance from the mass and energy balance equations one needs to know inputs such as the type of refrigerant-absorbent mixtures used in the system, operating temperatures, composition of solution at the entry and exit of absorber, effectiveness of solution heat exchanger etc. A simple steady flow analysis of the system will be presented in later sections.

1.6. Refrigerant-absorbent combinations for VARS

The desirable properties of refrigerant-absorbent mixtures for VARS are:

- i. The refrigerant should exhibit high solubility with solution in the absorber. This is to say that it should exhibit negative deviation from Raoult's law at absorber.
- ii. There should be large difference in the boiling points of refrigerant and absorbent (greater than 200 °C), so that only refrigerant is boiled-off in the generator. This ensures that only pure refrigerant circulates through refrigerant circuit (condenser-expansion valve-evaporator) leading to isothermal heat transfer in evaporator and condenser.
- iii. It should exhibit small heat of mixing so that a high COP can be achieved. However, this requirement contradicts the first requirement. Hence, in practice a trade-off is required between solubility and heat of mixing.
- iv. The refrigerant-absorbent mixture should have high thermal conductivity and low viscosity for high performance.
- v. It should not undergo crystallization or solidification inside the system.

vi. The mixture should be safe, chemically stable, non-corrosive, inexpensive and should be available easily.

The most commonly used refrigerant-absorbent pairs in commercial systems are:

1. Water-Lithium Bromide (H_2O -LiBr) system for above $0^\circ C$ applications such as air conditioning. Here water is the refrigerant and lithium bromide is the absorbent.
2. Ammonia-Water (NH_3 - H_2O) system for refrigeration applications with ammonia as refrigerant and water as absorbent.

Of late efforts are being made to develop other refrigerant-absorbent systems using both natural and synthetic refrigerants to overcome some of the limitations of (H_2O -LiBr) and (NH_3 - H_2O) systems. Currently, large water-lithium bromide (H_2O -LiBr) systems are extensively used in air conditioning applications, whereas large ammonia-water (NH_3 - H_2O) systems are used in refrigeration applications, while small ammonia-water systems with a third inert gas are used in a pump less form in small domestic refrigerators (triple fluid vapour absorption systems).