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The degradation of ammonia in absorption thermal machines

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Abstract

When water-ammonia absorption machines are used as heat pumps, the main problems can be found in the components operating at a high pressure (generator-condenser); the increase in temperature with respect to the exertion as refrigerator generates particular conditions that might unbalance the decomposition of ammonia into nitrogen. A decrease in the rate of the refrigerating fluid NH_3 in the condenser and evaporator occurs, hence of the performance coefficient of the heat pump with an increased risk of the potential generation of explosive mixtures due to the presence of the hydrogen. The aim of this study is to examine the reaction of ammonia during the dissociation process from a thermodynamic and thermokinetic point of view, focusing on the temperatures and pressures of a heat transformer. With the generator at a temperature of 170 °C it is necessary to reach a degree of dissociation at 1% a time period of the order of 1.013 seconds which is 100 times higher than the one of maximum permanence of the fluid in the components of the machines functioning at high temperatures. This is not a problem that might prevent the realization of high temperature absorption heat pumps.

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Keywords: thermochemical dissociation, heat pumps, absorption machines, ammonia.

1. Introduction

Energy issues' assessment has always been one of the most important engineering research sectors and it has been performed with respect to different fields [1-13]. In particular, this study stems from the fact that absorption heat pumps allow a redistribution on new thermal levels of different amounts of heat with low working values and they can be considered interesting machines from an energetic point of view.

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Then, for what concerns the working conditions as refrigerant machine, it is well known that the available fluids are the couple H_2O-LiBr and NH_3-H_2O [14-16].

Nomenclature

0	pure substance;
1	component 1 (ammonia);
2	component 2 (water);
C	concentration [mol m^{-3}];
C_0	concentration at the instant t = 0 [mol m^{-3}];
E_a	activation energy = 209.3 [kJ mol^{-1}];
g	generator;
K	Boltzmann constant = $1.38 \cdot 10^{-26}$ [kJ K^{-1}];
K_a, K_p	equilibrium constants;
K_V	reaction rate constant [m^3 mol^{-1} s^{-1}];
L	Avogadro's number = $6.02252 \cdot 10^{-23}$ [mol^{-1}];
P	total pressure [kg cm^{-2}];
R	gases universal constant = $8.314 \cdot 10^{-3}$ [kJ mol^{-1} K^{-1}];
t	time [s];
T	temperature [°C; K];
v	dissociation velocity [mol m^{-3} s^{-1}];
X	concentration [mol m^{-3}];
α	dissociation degree;
ΔG_f	free energy of formation [kJ kg^{-1}];
ΔG_r	variation in free energy of reaction [kJ kg^{-1}].

The variation in the heat levels characterizing the different sections with respect to the employment as refrigerant makes further problems arise and, even if other studies focused on similar topics [17-19], new solutions have not been found yet. Many studies have been carried out to examine the limits related to the traditional mixtures, in particular for what concerns the temperature of their exertion without causing problematic situations with a decrease in a crucial parameter as the reliability of the system [20-24]. The couple NH_3-H_2O presents problems in terms of high pressure (generator-condenser): the increase in temperature, for what concerns the exertion as refrigerator, provokes a higher fluid pressure thus causing the necessity of a proper mechanical dimensioning of the components, hence higher costs. Due to a higher temperature, an abundant amount of vaporous absorbent is moved to the generator with rectification difficulties. Moreover, the particular conditions in terms of temperature and pressure might unbalance the equilibrium of the decomposition reaction of the ammonia into nitrogen and hydrogen to high values of the dissociation degree [25]. Hence it occurs a decrease in the rate of the refrigerant fluid NH_3 in the condenser and evaporator, and of the coefficient of performance of the heat pump. There is also a higher probability that explosive substances (due to the presence of hydrogen) might generate.

2. Dissociation chemical reaction

The dissociation reaction of the ammonia into nitrogen and hydrogen is:

$$2NH_3 = N_2 + 3H_2 \tag{1}$$

If there is an equilibrium, that is pressure and temperature are constant, the variation in the free energy of reaction is provided by:

$$\Delta G_r = RTlnK_a \tag{2}$$