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Temperature Dependence of Thermodynamic Properties of Zn-5Al and Zn-55Al Alloys With Magnesium

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ABSTRACT

According to cooling law of Newton and studied experimental results, enthalpy, entropy and energy of Gibbs of Zn-5Al and Zn-55Al alloys were achieved and special heat capacity of the alloys with Mg were studied. Experimental research showed that increasing temperature due to increase enthalpy and entropy of Zn-5Al and Zn-55Al original alloys but energy of Gibbs decreases. After 500 K, increasing temperature due to soft increasing entropy. After adding small amounts of Magnesium to the original alloy, it is observed that increasing temperature due to increase the Special heat capacity of them, but about 520-530 K, a transition is observed which is explained by recrystallization of grains.

Keywords: Zn-5Al, Zn-55Al, Magnesium, Thermodynamic Properties, Enthalpy, Entropy, Energy of Gibbs, Special Heat Capacity.

INTRODUCTION

In recent years, the interest of researchers to zinc - aluminum alloy increased which due to use wide applications in various industries[1].

The urgency of protecting metals against the corrosion is one of the oldest technical problems. Requirements for corrosion resistance of materials widely depend on the destination of the product, conditions of the working, temperature, and the life of designed service. Products and structures which are made of metal[2]. They are the most significant and valuable part of the fixed assets of any industrialized country and their protection from corrosion is a major problem. For these industries, Studdying thermodynamic properties of alloys due to make ability to predict behaviors and modify the properties and make new alloys[3,4].

In recent years the Gulf alloys (Zn-5Al and Zn-55Al) which is the most useful Zinc - aluminum alloys are used to protect steel components. Magnesium is one of the elements in the second group of the periodic table is more active than zinc and aluminum and adding Specified amounts to the alloys can Mg obtained desired properties. Thermodynamic behavior of these alloys with Magnesium can provide useful information[5].

In the technical and public available literature we could not find any information about the heat capacity of the zinc alloys, therefore, we tried to identify thermodynamic parameters of the alloy to use and make new alloys.

EXPERIMENTAL

Experimental study of heat capacity of Zn-5Al and Zn-55Al alloy with Magnesium were carried out by cooling method, according to Newton law. Anything with a temperature above the ambient temperature will Mg cooled down and the cooling rate depends on the temperature and heat transfer coefficient. Therefore, heat transfer coefficient will Mg calculated to calculate heat capacity and then enthalpy, entropy and Gibbs energy will Mg obtained.

The measurements were performed with an instrument which is made with us[6]. Samples were a cylindrical shape with a diameter of 16 mm and 30 mm height. Aluminum grades A7, pure Zinc and Al-2%Mg were used. All processing results of measurements made with a program which is drawn up by MS Excel. Charts were constructed using Sigma Plot.

RESULTS AND DISCUSSION

Researches have shown that the dependence of temperature, T, of Zn-5Al and Zn-55Al on the cooling time, τ, obeys the following formula, respectively:

$$T = 304.4618 \exp(-0.0029\tau) + 338.2087 \exp(-0{,}000073627\tau),$$
$$T = 339.9876 \exp(-0.0016\tau) + 293.2836 \exp(-7.7123\ 10^{-14}\ \tau) \quad ...(1)$$

Differentiating (1) we obtain expressions of cooling rate of Zn-55Al and Zn-5Al, Respectively:

$$dT/d\tau = -0.883 \exp(-0.0029\tau) - 0.0249 \exp(-0.000073627\tau)$$
$$dT/d\tau = -0.544 \exp(-0.0016\tau) - 2.262\ 10^{-11} \exp(-7.7123\ 10^{-14}\ \tau) \quad ...(2)$$

Cooling rate of the Zn-5Al and Zn-55Al alloys will Mg calculated by (2). From the data on the rate of cooling and heat capacity, temperature dependence of the heat transfer coefficient can Mg calculated as follows:

$$a \quad \frac{Cm\dfrac{dT}{dt}}{(T-T_0).S}$$

Here m, and S are the mass and the surface of the samples, and T, T_0 are the temperature of the sample and the ambient, respectively.

Temperature dependence of heat transfer coefficient of Zn-55Al alloy is given by Fig.1. Increasing temperature, the rate of increasing heat transfer coefficient decreases at 500 K.

$$A(T) = -9.6891 + 0.0888T - 9.1909\ 10^{-5}\ T^2 + 2.9284\ 10^{-8}\ T^3 \quad ...(3)$$

The heat capacity of the alloy was calculated using the rule of Neumann - Kopp. Data on the heat capacity of zinc and aluminum A7 has been taken from references [7, 8] The heat capacities of Zn-5Al and Zn-55Al are expressed by the equation (J/kg.K):

$$C_p = 531.3600 + 0.6945T - 0.0010T^2 + 8.1887\ 10^{-7}T^3$$
$$C_P = 344.1600 + 0.3986T - 0.0007T^2 + 7.6520\cdot10^{-7}\ T^3 \quad ...(4)$$

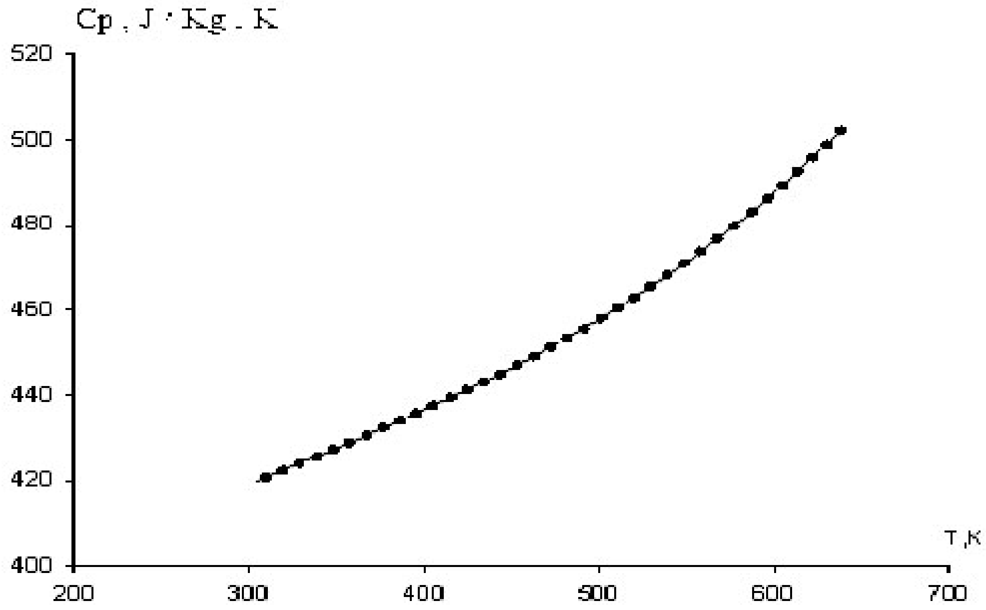

Fig.1 : Dependence of specific heat CP (T) of Zn -5Al alloy on temperature

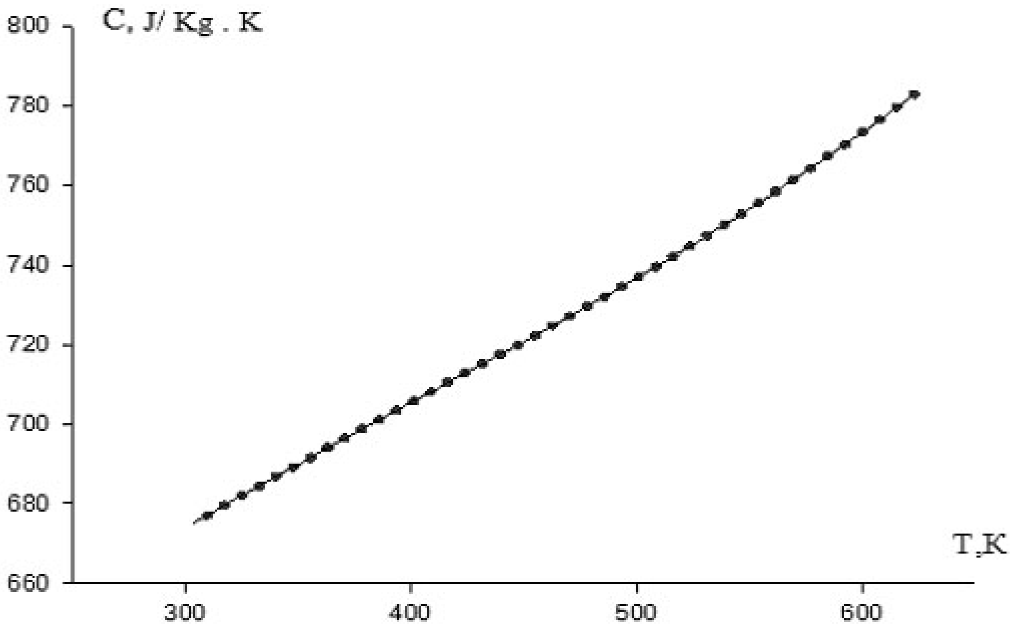

Fig.2 : Dependence of specific heat CP (T) of Zn -55Al alloy on temperature

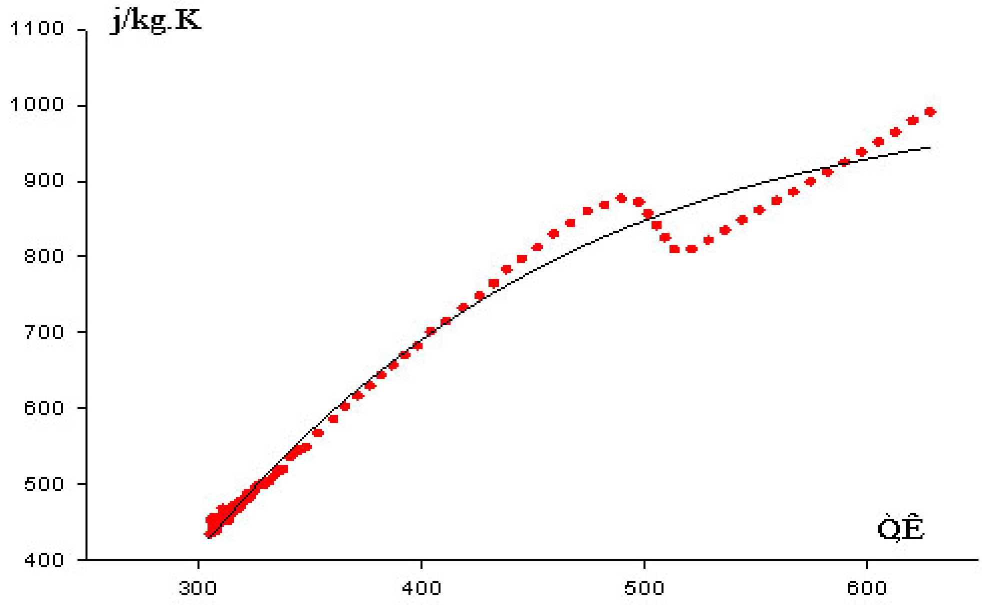

Fig.3. Dependence of specific heat $C_p(T)$ on temperature for Zn-5Al alloy with 1.0%Mg (points of curve have been calculated using the formula: $\tilde{N}_p = C_{p0} + mT + nT^2 + gT^3$).

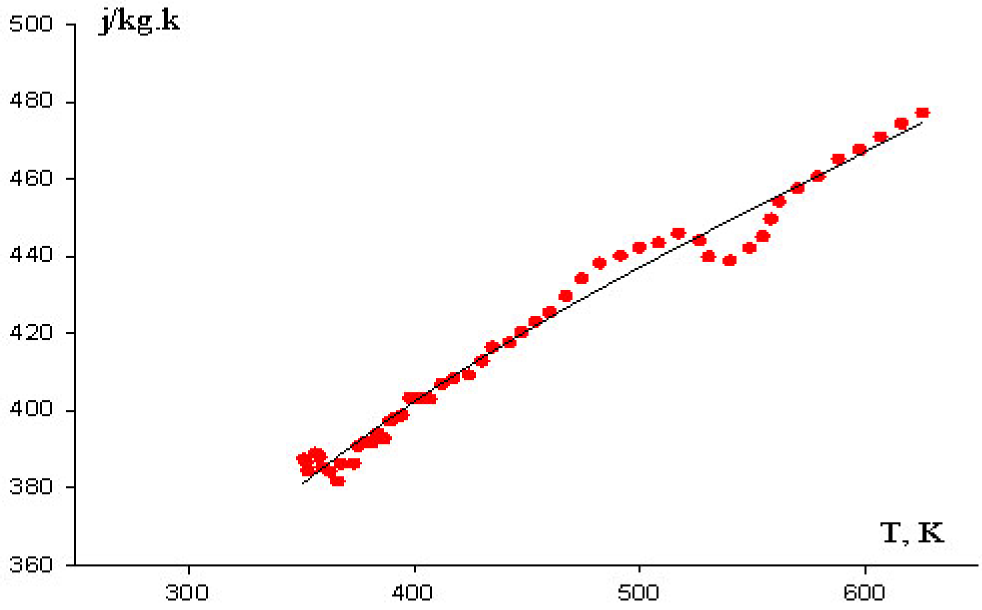

Fig.4 : Dependence of specific heat $C_p(T)$ on temperature for Zn-55Al alloy with 0.05%Mg (points of curve have been calculated using the formula: $\tilde{N}_p = C_{p0} + mT + nT^2 + gT^3$).

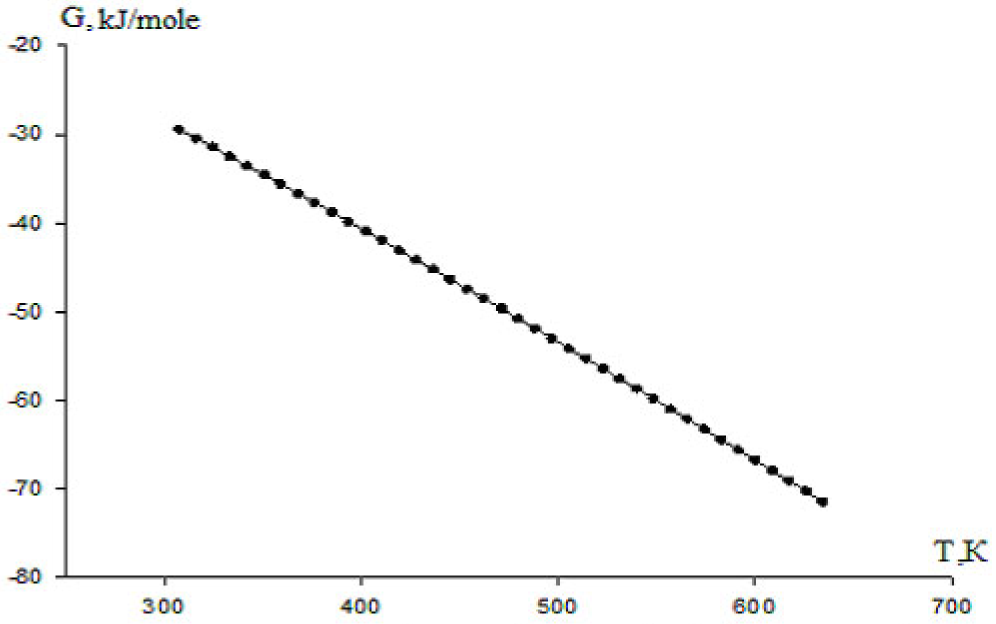

Fig. 5: Temperature dependence of Gibbs energy for the Zn-55Al Alloy

Fig. 1-4 shows the dependence of heat capacity of the alloy. In the alloys with Magnesium, a sharp decrease of heat capacity is observed about 520-530 K. It means that, recrystallization have been occurred about the temperature ranges. This rule is observed in all of the alloys with different amount of Magnesium.

Knowing the heat capacity allows to determine the change in enthalpy, entropy and Gibbs energy in accordance with the equation of Kirchhoff. Experimental measurement of heat capacity for different temperature ranges is the primary method for determining the thermodynamic parameters of the material. The temperature range which we used in the integrals of the molar heat capacity are 0 to T, they are used to calculate the change in enthalpy and entropy of the objects:

$$H(T)=H(0)+\int C_p(T)dT,$$
$$S(T)=\int C_p(T)d\ln T,$$
$$G(T)=H(T)-T\,S(T)$$ [9]

We obtain the following equations for temperature dependence of enthalpy (J/mol):

$$H(T) = 19.53545\,T+1.2765\,10^{-2}\,T^2-1.223\,10^{-5}\,T^3+7.525\,10^{-9}\,T^4,$$
$$H(T) = 20.9938\,T+1.2157\cdot10^{-2}\,T^2-1.4233\cdot10^{-5}T^3+4.6677\cdot10^{-9}\,T^4 \quad ...(5)$$

entropy (J/mol K):

$$S(T)=19.53545\ln T+2.553\,10^{-2}\,T-1,835\,10^{-5}\,T^2+1.0033\,10^{-8}\,T^3,$$
$$S(T)=20.9938\ln T+2.4315\cdot10^{-2}\,T-2.135\cdot10^{-5}\,T^2+1.5559\cdot10^{-8}T^3 \quad ...(6)$$

And Gibbs energy of Zn-5Al and Zn-55Al alloys respectively (J/mol):

$$G(T) = -19.53545\,T(\ln T-1)-1.2765\,10^{-2}\,T^2+6.12\,10^{-6}\,T^3-2.508\,10^{-9}\,T^4.$$
$$G(T) = -20.9938\,T(\ln T-1)-1.2158\cdot10^{-2}\,T^2+7.117\cdot10^{-6}\,T^3-3.89\cdot10^{-9}\,T^4 \quad ...(7)$$

For example Fig. 5 shows the dependence of Gibbs energy of Zn-55Al on temperature.

CONCLUSION

Dependence of temperature on time, cooling rate , heat transfer coefficient , specific heat , enthalpy , entropy and Gibbs energy of Zn-5Al and Zn-55Al alloys have been obtained.

In all these systems a sharp decrease of heat capacity is observed about 520-530 K. It means that, recrystallization have been occurred about the temperature ranges. This rule is observed in all of the alloys with different amount of Magnesium.

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