The Lattice Specific Heat of $RENi_5$ Compounds at Low Temperatures

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Abstract

The lattice specific heat ,C_L, and Debye temperatures , $\theta_D(o)$,of the rare earth metals with nickle compounds ($RENi_5$) have been estimated at low temperatures (T<30K) by scaling results of the specific heat of the non-magnetic compound $LaNi_5$. The magnetic specific heats,C_m, and the magnetic entropy,S_m, in some magnetic $RENi_5$ compounds have also been recalculated and compared with the other published results.

Introdution

The rare earth Nickle($RENi_5$)intermetallic cmopounds have the C_aC_{u5} structre at room temperature.The magnetic $RENi_5$ compounds(excpt $PrNi_5$ which exhibits a ferro- to paramagnetic transition with curie temperature of 15 K), The magnetic proprties of these compounds have been investigated by many authors.(Wells et al,1979 ;Mohammed,2003; Gorem,1984;Craig, 1972; Abrahams et al,1964;Escudler et al, 1977) but the thermal properties ,and especially specific heat ,have received less attention.(Andres et al,1975;Wernich,1959)have the specific heats of T_bNi_5,G_dNi_5,and E_rNi_5 compounds have also been measured.

(Mohammed, 2003;Gorem,1984) but were studied were the proprties in the temperature range from 2 to 50K-In general, the total specific heat of solid materials can be written as ;

$$C_p = C_e + C_L + C_m \quad ...(1)$$

Where C_e, C_L and C_m represent the electronic, lattice and magnetic specific heats respectively.Studies of the specific heats of $RENi_5$ compounds have faced a great problem in the separation of the magnetic specific heat C_m from the total spcific heat C_p .The accuracy of tha resultant values of C_m are in great doubt due to the error in the estimation of lattice spcific heat.

These estimation methods can be summenzed as follows:

The first method is to measure the spcific heat of a similar but non-magnetic compound and then use ithas representative of a non-magnetic specific heat(Ushizaka et al,1984). In this regard, $LaNi_5$ is the best non-magnetic compound used this respect.The second method(Seipler et al,1977) is a the computer to get the best fit equation for the matezials C_p .

The Lattice Specific Heat Predictions

In order to study the magnetic specific heat more carefully it has to be extracted from the total specific heat, i.e., the lattice specific heat has to be estimated accurately by a reliable method.In this study we have estimated the lattice specific heat and Debye temperatures for all $RENi_5$ compounds by scaling the results of the lattice specific heat of stable, non-magnetic and quite similar compound ,$LaNi_5$. The principles of this method(Naji et al, 1989, Lanchester et al, 1987) are based on Debye theay,which assumes that lattice specific heats of all compound fit a universal funciton of $T/\theta_D(0)$,where the values of the Debye temperature $\theta_D(0)$ should be proportional (according to Lindemanns function) the inverse of square root of the mean atomic mass, i.e.

$$\theta_D(o) \propto M^{-0.5} \quad .$$

Moreover, by using the scling apprach , many universal functions have been introduced to characterise the experimental results, such as the specific heat, magnetisation,susceptibility and electrical resistiviy(Souletic et al, 1969) This seems to be quite true for similar highly correlated compounds such as $RENi_5$ compounds in which values of the force constants are expected to change gradually from one compound to another . Accordingly,the Debye temperture of any $RENi_5$ compound can be obtained by the following equation.

$$\ldots(2)\ \theta_D(0)(RENi_5) = \theta_D(0)(LaNi_5)\frac{\langle MLaNi_5\rangle^{0.5}}{\langle MRENi_5\rangle^{0.5}}$$

where the value of $LaNi_5$ θ_D (0) has been found from the C/T versus T^2 plot to be equal to 147K.(Mohammed 2003) Resultant of $\theta_D(0)$ for $RENi_5$ compounds are shown in Table 1 . It is clear from this table that there is a significant difference between values of $\theta_D(0)$ in this stady and that in other investigations.The lattice specific heat of any of these compounds can be estimated by scaling values of C_L for $LaNi_5$ at a temperature T, to a new temperature T^- , where

$$T' = T\frac{\theta_D(0)[RENi_5]}{\theta_D(0)[LaNi_5]} \qquad \ldots(3)$$

where value s of $\theta_D(0)$for any $RENi_5$ compound can be found from table(1). The lattice specific heats obtained by this method for rare earth-nickle compound are shown in figs.1 and 2 respectively. The variation of the

Debye temperatures $\theta_D(0)$ with tempertaure for these compounds can now be estimated using the well known relation

$$\theta_D(0) = \left|\frac{1944}{C_L}\right|^{1/3} T..(\mathrm{K}) \qquad \ldots(4)$$

The varition of $\theta_D(0)$ with tempearture for some of rare earth-nickle compounds is shown in figs 3,4 and 5 respectively.

Table 1: Values of Debye temperature $\theta_D(0)$ for $RENi_5$ compounds.

	$\theta_D(0) \pm 0.5K^0$	$\theta_D(0) \pm 0.5K^0$
RENi5 compounds	work $\theta_D(0)K^0$	$\theta_D(0)K^0$ (other studies)
$LaNi_5$	147	142k (Aoyacim et al ,1971)
$CeNi_5$	146.79	
$PrNi_5$	146.66	
$NdNi_5$	146.64	
$PmNi_5$	145.64	
$SmNi_5$	145.09	
$EuNi_5$	144.83	
$GdNi_5$	143.97	
$TbNi_5$	143.71	
$DyNi_5$	143.14	
$HoNi_5$	142.76	
$ErNi_5$	142.40	
$TmNi_5$	142.14	
$YbNi_5$	141.52	
$LuNi_5$	141.22	

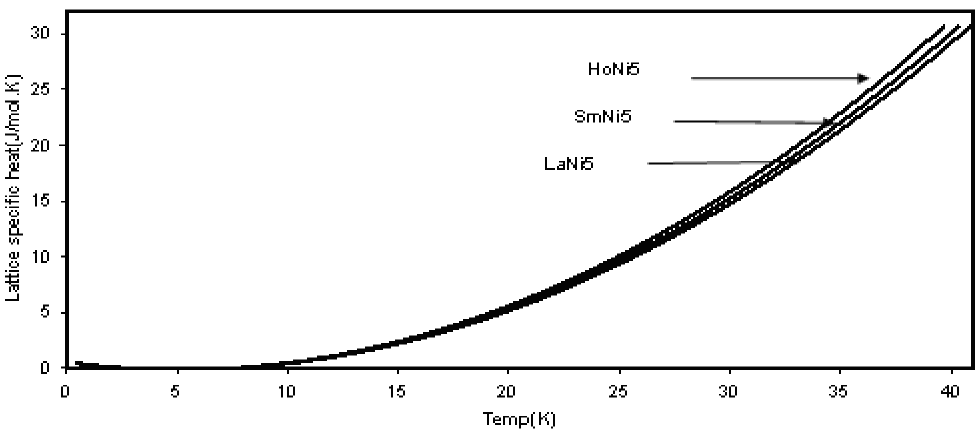

Fig 1: The predicted lattice specific heats,C_L versus temperature T for some rare earth nical ($RENi_5$) compound.

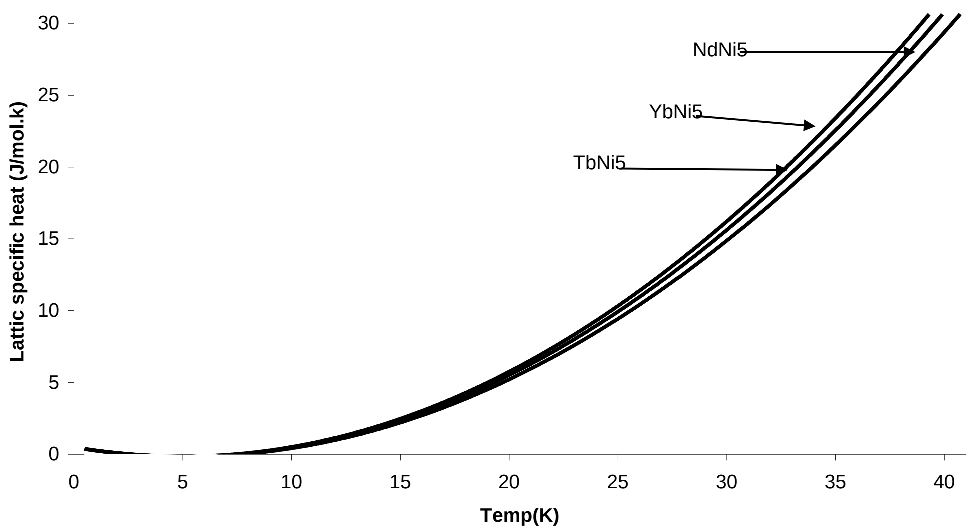

Fig. 2 : The predicted lattice specific heats, C_L versus temperature T for some rare earth nical ($RENi_5$) compound.

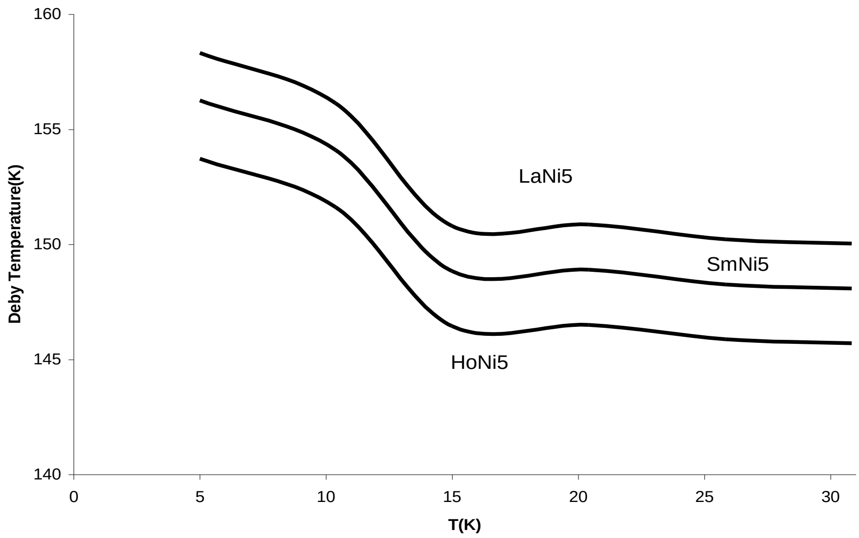

Fig 3: Debye temperature, θ_D (T) temperature T for some rare earth- nical ($RENi_5$) compound.

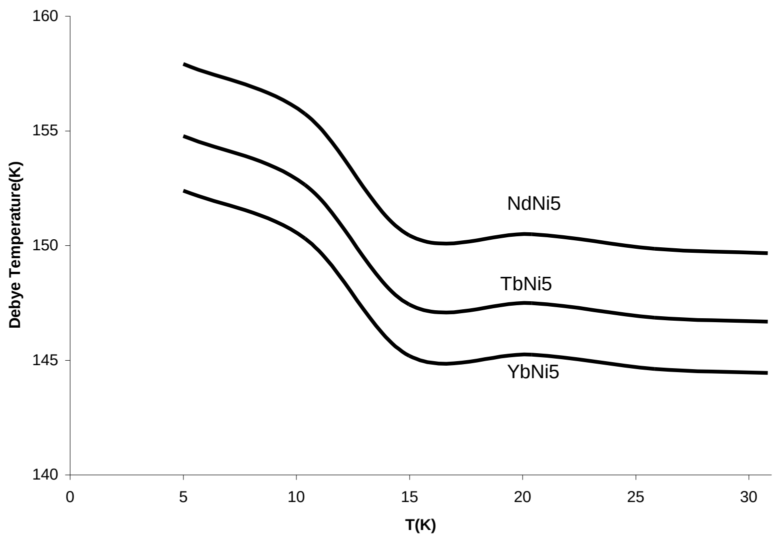

Fig 4: Debye temperature,θ_D (T) temperature T for some rare earth- nical ($RENi_5$) compound.

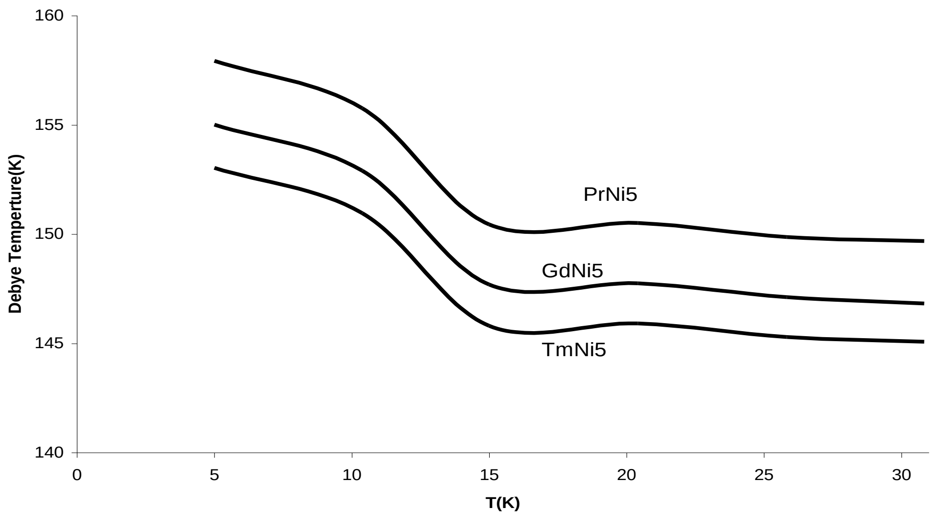

Fig 5: Debye temperature,θ_D (T) temperature T for some rare earth- nical ($RENi_5$) compound.

It has been mentioned earlier that the error estimating the lattice specific heat for $RENi_5$ compounds causes a sigmificant error in the estimation of the magnetic specific entropy changes , especially for compounds with an ordering temperatur higher than 10K.In spite of that and in order to show quantitativly the error in C_m caused by using the usual methods we have recalculated the magnetic specific heats C_m of some of these compounds using new values of the lattice specific heats calculated using equation 2 . As an example of the magnatic specific heats of some $RENi_5$ compounds are shown in Figs. 6 and 7 for $GdNi_5$, $ErNi_5$ respcetively. Moreover ,the magnetic entropy S_m changes in these compounds from T=0 to $T=T_m$,where Tm is the temperture of the maximum magnetic specific heat ,are also recalculated using new values of C_m .Table 2 shows these results.

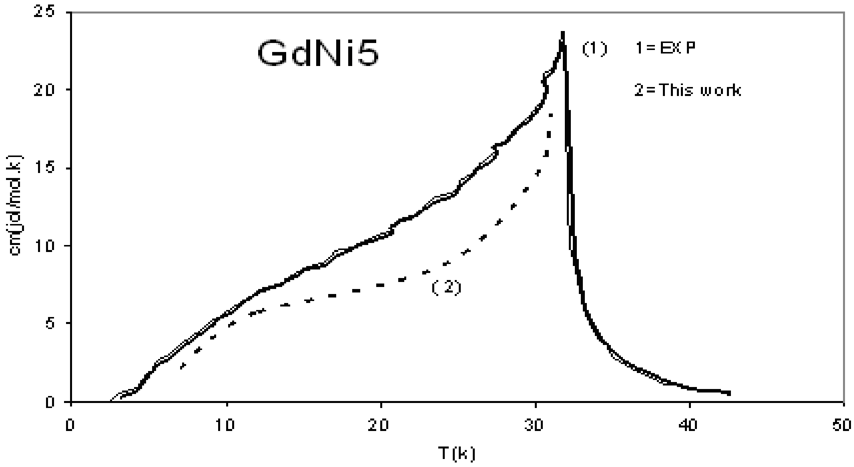

Fig.6: C_m versus T for G_dNi_5.

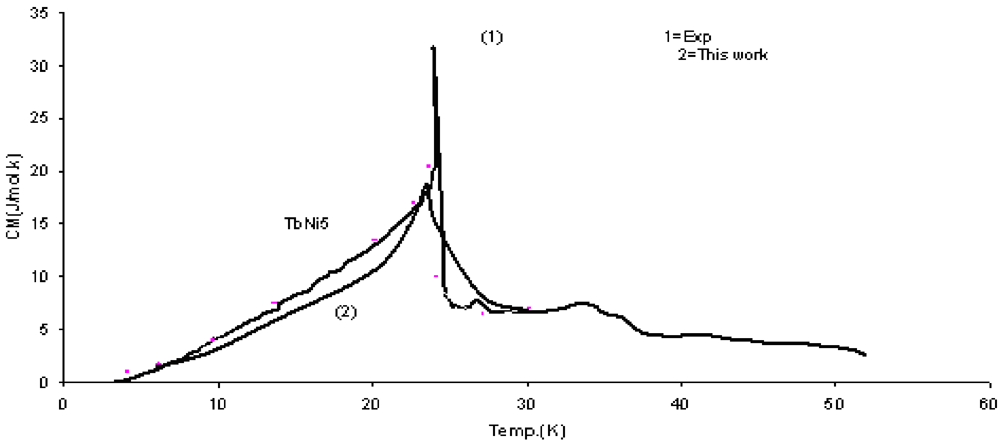

Fig 7: C_m versus T for T_bNi_5

Table 2: values of magnetic entropy changes S_m for $RENi_5$ compounds.

Some $RENi_5$ Compound	T_m(K)	T_c orT_N (K)From other refs	S_m/R.Ln (2J+1) (%)	S_m 0- T_m J/mol.k	This work
L_aNi_5	Non-magnetic	------	------	------	-----
G_dNi_5	32	32 (Abrahms,1964)	95	16.4	16
T_bNi_5	23.7	27(Gignonx etal,1979)	49	10.6	10.2
$G_{d2}o_3$	3.8	3.6(Nasa et al 1971)	----------	--------	------
$T_{b2}o_3$	2.4	2.4 (Hill,1986)	---------	--------	------

Conclusions

The principles of Debye theory and Lindemannns equation can be used to estimate the lattice specific heats of $RENi_5$ compounds. The magnetic lspecific heats and magnetic entropy of some of these compounds have also been recalculated using lattice specific heats as optained by this method .In spite of the rather large mass difference between RE and La metals the use of this method is quite satisfactory and can be used in analysing magnetic heats in other $RENi_5$ cmpounds at low temperature (< 30K). It results in an accurate estimation of C_m , which allows studying the validity of the $T^{3/2}$ and T^3 laws for ferro- and antiferromagnetic $RENi_5$ compounds at low temperature .morover, this method might also be shown to be valid for high temperature ranges.

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الحرارة النوعية للشبيكة لمركبات النادرة مع النيكل في درجات الحرارة الواطئة

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الخلاصة

تم حساب الحرارة النوعية للشبيكة C_L لمركبات العناصر النادرة مع النيكل حيث أن [RE] عنصر نـــادر، وكذلك تم حساب درجة حرارة ديباي $\theta_D(o)$ من خلال تدريج الحرارة النوعية للمركـــب غيـــر المغناطيســـي $LaNi_5$. كما تم حساب الحرارة النوعية المغناطيسية C_m والأنتروبي المغناطيســـي S_m للمركبـــات $RENi_5$ المغناطيسية ومن ثم مقارنة النتائج المستحصلة مع نتائج الدراسات السابقة.