

Experiments with Liquid Nitrogen:

Latent Heat of Vaporization, Specific Heat Capacity of Tin, Molar Gas Constant

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In this intuitive experiment, the latent heat of vaporization of liquid nitrogen and the specific heat capacity of tin were calculated using a simple experimental set up. We also determined the value of the molar gas constant and learned about the safe handling of cryogenics. We learnt the cutting of metals, some of them toxic, with proper safety precautions.

KEYWORDS

Latent heat of vaporization · Specific heat capacity · Cryogenics · Ammeter · Voltmeter·

1 Safety Measures

1.1 Handling Liquid Nitrogen

Liquid nitrogen has a very low temperature and direct contact with it can be dangerous. Thus, safety gloves and goggles should be used while handling liquid nitrogen. Liquid nitrogen has a high evaporation rate and if liquid nitrogen is kept in a sealed container, the container can explode.

1.2 Using Toxic Metals

The materials that we have used in our experiment are toxic (e.g. lead and tin). To avoid contact with these materials, we used gloves.

1.3 Using Hand saw and Grinder

During our internship, we used a handsaw and grinder to shape our metals into the desired shapes. We had to make sure we gripped the grinder firmly, loose grip may cause serious injury. To avoid metal filings entering the eyes, safety goggles were used. Furthermore, the cutting and filing of metals were performed in an enclosed area as the toxic filings scattered in all directions. As mentioned earlier, we wore gloves to avoid contact with these metals.

2 Cooling Baths

Different cooling baths were made using,

1. $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$ and crushed distilled ice (2.5:1) to achieve -10°C ,
2. NaCl and crushed distilled ice (1:3) to achieve -10°C and -20°C ,
3. CCl_4 and liquid nitrogen (-20°C),
4. Dry ice and acetone (-78°C),
5. Methanol and liquid nitrogen (-98°C),
6. Ethanol and liquid nitrogen (-116°C).

3 Cutting of Metals

3.1 Using Hand saw

In this activity, we cut the metals using a hand saw and the rough surfaces were made smooth using a filer. The metal blocks (lead and tin) were placed in the vise to hold firmly and cubes of different dimensions were taken off. The dimensions of the lead cubes taken out were 1.6 cm each and for tin, two cubes of dimensions 2.0 cm each were extracted.



Lead



Tin

3.2 Using Grinder

We worked with the grinder to make the surfaces smooth of these metal cubes.



Working with a grinder.

4 The Experiment

In this experiment, we first observed the background rate of evaporation of liquid nitrogen. The rate increased when the heating was turned on and re-established when the heating was turned off. The change in mass of liquid nitrogen during the entire process was calculated after processing data in Matlab. The latent heat of vaporization of liquid nitrogen was calculated using the Equation,

$$L_v = \frac{VI\Delta t}{\Delta m}, \quad (1)$$

where V is the voltage supplied to the heater dipped inside the refrigerant, I is the current through the heater, Δt is the time for which the heating is turned off and Δm is the decrease in mass over the time. The calculated value of latent heat of vaporization is 183 ± 4 kJ/kg whereas the accepted values is 197.5 kJ/kg (Lide, D.R (2004), *CRC Handbook of Chemistry and Physics*, pp 1 – 54).

The experiment was further extended to calculate the specific heat capacity of tin metal. Following the same procedure, we replaced the heater with a cube

of tin metal. Again, the change in mass was calculated using Matlab. Specific heat capacity of tin was calculated using the following equation,

$$C_p = \frac{198\Delta m}{(T_o - 77)n}, \quad (2)$$

where Δm is the change in the mass due to heating and n is the number of moles of the solid. The experiment was repeated at different temperatures, which were achieved using the cold baths mentioned above.

5 Results

The data for all these attempts is given in Table 1.

Temperature (K)	204	229.8	257.5	273	286	300
Specific heat (J/kgK)	19.31	24.81	26.10	23.96	27.06	25.96
Uncertainty (J/kgK)	± 0.03	± 0.03	± 0.02	± 0.02	± 0.02	± 0.02

Table 1: Specific heat at different temperatures.

The value of specific heat capacity of tin increases as the temperature increases, and then plateaus off. The high temperature specific heat should be equal to $3nRT$, this is the famous Dulong-Petit Law. Specific heat of tin at different temperatures is shown in the Figure 1.

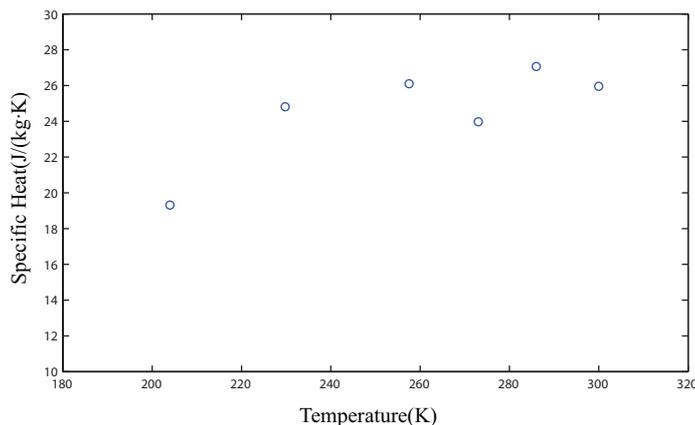


Figure 1: Specific Heat vs Temperature.

This data can be used to calculate the value of the molar gas constant, R . The values of R obtained is $0.0742 \text{ atm L K}^{-1}\text{mol}^{-1}$ (at $T = 286 \text{ K}$) and $R = 0.0795 \text{ atm L K}^{-1}\text{mol}^{-1}$ ($T = 257.5 \text{ K}$), where the relationship used is,

$$R = \frac{C_p}{3nT}. \quad (3)$$

The accepted value of R is $0.0821 \text{ atm L K}^{-1}\text{mol}^{-1}$ (Lide, D.R (2004), *CRC Handbook of Chemistry and Physics*, pp 1 – 54).

6 Conclusions

The value of the specific heat capacity is constant for all metals but there is slight variation at low temperatures and this behavior is depicted in the temperature vs specific heat capacity graph. We use the data to calculate the molar gas constant. Our results are in close agreement with established values. We learned the safe use of cryogenics and also the cutting and grinding of metals. We also determined the latent heat of vaporization of liquid nitrogen.