Stefano F. PHYS 212 2/13/21

Lab 3: Latent Heat of Fusion.

Results:

Trial 1:

$(kg)\ m_d \pm \delta m_d$	$(kg)\ m_{w+d} \pm \delta m_{w+d}$	$(kg)\ m_w \pm \delta m_w$	$(K)\ T_{ice} \pm \delta T_{ice}$	$(K)\ T_h \pm \delta T_h$	$(K)\ T_f \pm \delta T_f$	$(kg)\ m_{w+d+ice} \pm \delta m_{w+d+ice}$	$(kg)\ m_{ice} \pm \delta m_{ice}$
.405 kg	.575 kg	.17 kg	273.15	323.65	286.65	.662 kg	.087 kg
.001 kg	.001 kg	.001 kg	1	3.5	.1	.001 kg	.001 kg

Trial 2:

$(kg)\ m_d \pm \delta m_d$	$(kg)\ m_{w+d} \pm \delta m_{w+d}$	$(kg)\ m_w \pm \delta m_w$	$(K)\ T_{ice} \pm \delta T_{ice}$	$(K)\ T_h \pm \delta T_h$	$(K)\ T_f \pm \delta T_f$	$(kg)\ m_{w+d+ice} \pm \delta m_{w+d+ice}$	$(kg)\ m_{ice} \pm \delta m_{ice}$
.405 kg	.579 kg	.174 kg	273.15	334.15	228.35	.680 kg	.101 kg
.001 kg	.001 kg	.001 kg	1	3.5	.01	.001 kg	.001 kg

Trial 3:

$(kg)\ m_d \pm \delta m_d$	$(kg)\ m_{w+d} \pm \delta m_{w+d}$	$(kg)\ m_w \pm \delta m_w$	$(K)\ T_{ice} \pm \delta T_{ice}$	$(K)\ T_h \pm \delta T_h$	$(K)\ T_f \pm \delta T_f$	$(kg)\ m_{w+d+ice} \pm \delta m_{w+d+ice}$	$(kg)\ m_{ice} \pm \delta m_{ice}$
.405 kg	.637 kg	.232 kg	273.15	346.55	293.45	.868 kg	.231 kg
.001 kg	.001 kg	.001 kg	1	3.5	.1	.001 kg	.001 kg

Computing L_f:

Looking at our spreadsheet data, trial 2 has the lowest percent error. So we will demonstrate the calculations using trial 2.

$$L_f = \frac{c_w m_w + C_d}{m_{ice}}(T_h - T_f) + c_w(T_{ice} - T_f).$$

First, recall the given values,

$C_d : 83 \pm 5\ J/°C$ $\qquad$ $c_w : 4186\ J/kg\,°C$

Since the given values are in terms of Celsius, we will convert back,

$$T_h = 61.0^\circ C \qquad T_f = 15.2^\circ C \qquad T_{ice} = 0^\circ C$$

Finally substituting our values we get,

$$L_f = \frac{(4,186)(.174)+83}{.101}(61.0-15.2) + 4,186(-15.2)$$

$$= 304,298.257 \text{ J/kg}$$

<u>Uncertainty:</u>

Recall that in lab 1 we found the uncertainty equation for dL_f. Computing the partial derivatives,

$$dm_w \frac{dL}{dm_w} = dm_w \frac{c_w}{m_{ice}}(T_h - T_f) = .001\,\frac{4,186}{.101}(61.0-15.2) = 1,898.2$$

$$c_d \frac{dL}{dc_d} = \frac{c_d}{m_{ice}}(T_h - T_f) = \frac{5}{.101}(61.0-15.2) = 2267.33$$

$$dT_f \frac{dL}{dT_f} = dT_f\left(\frac{c_w m_w + c_d}{m_{ice}} + c_w\right) = .1\left(\frac{4,186(.174)+83}{.101} + 4186\right) = 1221.93$$

$$dm_{ice} \frac{dL}{dm_{ice}} = dm_{ice}\left(\frac{c_w m_w + c_d}{m_{ice}^2}\right)(T_h - T_f) = .001\left(\frac{4,186(.174)+83}{(.101)^2}\right)(61.0-15.2)$$

$$= 3642.83$$

$$dT_h \frac{dL}{dT_h} = dT_h\left(\frac{c_w m_w + c_d}{m_{ice}}\right) = 3.5\left(\frac{4,186(.174)+83}{(.101)^2}\right) = 28,116.57$$

$$dT_{ice} \frac{dL}{dT_{ice}} = dT_{ice}\, c_w = 1(4,186) = 4,186$$

Now we can plug in our values into the uncertainty formula,

$$\partial L = \left(\left(\frac{\partial L}{\partial m_w} m_w\right)^2 + \left(\frac{\partial L}{\partial L_d} L_d\right)^2 + \left(\frac{\partial L}{\partial T_f} T_f\right)^2 + \left(\frac{\partial L}{\partial m_{ice}} m_{ice}\right)^2 + \left(\frac{\partial L}{\partial T_w} T_w\right)^2 + \left(\frac{\partial L}{\partial T_{ice}} T_{ice}\right)^2 \right)^{1/2}$$

$$= \left((1{,}898.2)^2 + (2{,}267.33)^2 + (1221.93)^2 + (3{,}642.83)^2 + (28{,}116.57)^2 + (4.186)^2 \right)^{1/2}$$

$$= 28836.98 \text{ J/kg}$$

Thus $L_f = 304{,}298.257 \pm 28836.98$ J/kg

Calculating our percent error.

$$\left| \frac{334{,}000.000 - 304{,}298.257}{334{,}000.000} \right| \times 100 = 8.893\%$$

From our calculations trial 2 gives us a latent heat value within 20% of the accepted value.

Raw Results:

The following is the calculations and results using the given excel calculator.

Trial 1:

Masses (kg)									
Mdewar	δMdewar	Mdewar+water	Mdewar+wate	Mwater*	δMwater	dewar+water+i	dewar+water+	Mice*	δMice
0.405	0.001	0.575	0.001	0.17	0.001	0.662	0.001	0.087	0.001
Temperatures (°C)						Cw [J/(kg°C)]		Cd (Large J/°C)	Cd (Small)
Tice	δTice	Thot water	δhot water	Tfinal	δTfinal				
0	1	50.5	3.5	13.5	0.1	4186		83	71
								5	6
Lf (Large)					δLf (Large)				
281430.8391					32618.94287				
Percent Error (%)		15.73926974			Range	248811.8962		314049.7819	

Details of Calculations (Partial Derivatives required to compute the uncertainties) *			
MwaterCw/Mice (Thot water-Tfina	δCd (Thot water-Tfinal)/Mice*	ice((CwMwater+Cd)/Mice2)(Thot water-Tfina	δLf (Large)*
1780.252874	2126.436782	3884.388955	
δTfinal((CwMwater+Cd)/Mice+Cw)	ot water(CwMwater+Cd)/Mic	δTiceCw*	32618.94287
1331.956322	31967.47126	4186	

Trial 2:

Masses (kg)									
Mdewar	δMdewar	Mdewar+water	Mdewar+wate	Mwater*	δMwater	dewar+water+i	dewar+water+	Mice*	δMice
0.405	0.001	0.579	0.001	0.174	0.001	0.68	0.001	0.101	0.001
Temperatures (°C)						Cw [J/(kg°C)]		Cd (Large J/°C)	Cd (Small)
Tice	δTice	Thot water	δhot water	Tfinal	δTfinal				
0	1	61	3.5	15.2	0.1	4186		83	71
								5	6
Lf (Large)					δLf (Large)				
304298.2574					28836.98317				
Percent Error (%)		8.892737298			Range	275461.2743		333135.2406	

Details of Calculations (Partial Derivatives required to compute the uncertainties) *			
MwaterCw/Mice (Thot water-Tfina	δCd (Thot water-Tfinal)/Mice*	ice((CwMwater+Cd)/Mice2)(Thot water-Tfina	δLf (Large)*
1898.205941	2267.326733	3642.826311	
δTfinal((CwMwater+Cd)/Mice+Cw)	ot water(CwMwater+Cd)/Mic	δTiceCw*	28836.98317
1221.930693	28116.57426	4186	

Trial 3:

Masses (kg)									
Mdewar	δMdewar	Mdewar+water	Mdewar+wate	Mwater*	δMwater	dewar+water+i	dewar+water+	Mice*	δMice
0.405	0.001	0.637	0.001	0.232	0.001	0.868	0.001	0.231	0.001
Temperatures (°C)						Cw [J/(kg°C)]		Cd (Large J/°C)	Cd (Small)
Tice	δTice	Thot water	δhot water	Tfinal	δTfinal				
0	1	73.4	3.5	20.3	0.1	4186		83	71
								5	6
Lf (Large)						δLf (Large)			
157342.2571						16635.51031			
Percent Error (%)		52.89153978				Range	140706.7468		173977.7674
Details of Calculations (Partial Derivatives required to compute the uncertainties) *									
MwaterCw/Mice (Thot water-Tfinal		δCd (Thot water-Tfinal)/Mice*		ice((CwMwater+Cd)/Mice2)(Thot water-Tfina			δLf (Large)*		
962.2363636		1149.350649		1048.995918					
Tfinal((CwMwater+Cd)/Mice+Cw)		ot water(CwMwater+Cd)/Mic		δTiceCw*			16635.51031		
874.9428571		15972		4186					

Using this data we can quickly calculate an avg $(L_f \pm \delta L_f.)$ We will omit trial 3 as it has a percent error larger than 20%.

So,

$$Avg(L_f \pm \delta L_f) = 292864.548 \pm 30729.463 \text{ J/kg}$$

Conclusion:

a.) We dry the cubes because we assume in our experiment that $T_{ice} = 0°C$. The thin layer of water on the outside of the ice cube is $> T_{ice}$ since it is in liquid form.

10.) Trial 2 had the lowest percent error. I think that trial 1 and trial 3 hadn't reached equilibrium, so their final temps are a few degrees higher than they should be. I also feel like I didn't dry the ice enough for trial 3.

11.) None of my trials agree with the excepted value. They all fall just under the excepted value with trial 2 being the closest.

12.) Of the variables that we observed we would notice the least change in uncertainty by disregarding variables in this order.

Smallest Δ uncertainty

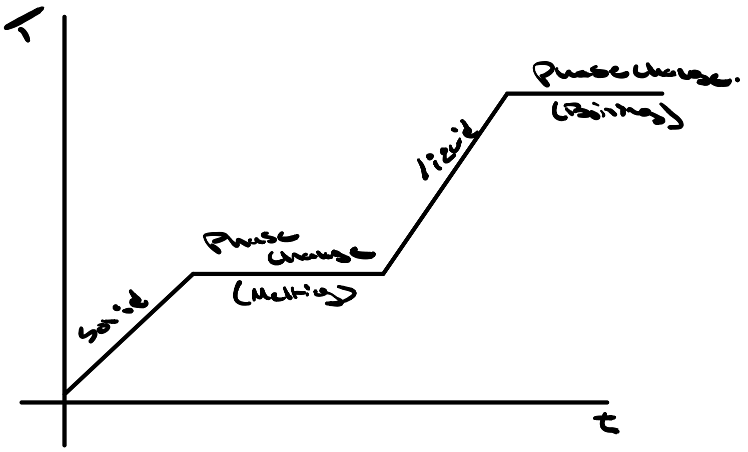
T_f, M_w, C_c, M_{ice}, T_{ice}, T_h

Largest Δ uncertainty

We can see this by observing our uncertainty calculations.

13.) Minerals in both the ice and the hot water would affect the latent heat. Any other material inside the dewar could also affect the latent heat. If the water was boiling then the very small amount of steam released would mess up the mass of the water.

14.) Consider the heating curve.



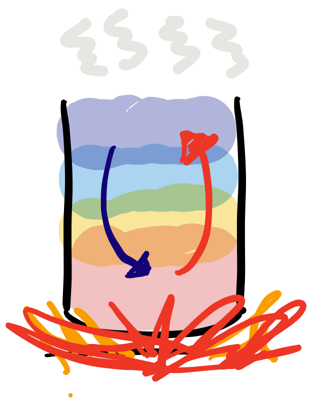
Once the ice reaches it's melting point, all kinetic energy added to the system goes into breaking the bonds between molecules. Therefore any heat added is stored as potential energy.

Liquid energy:

ΔTemp $\Rightarrow$ ΔKE of Molecules

Δphase $\Rightarrow$ ΔPE of Molecules

15.) An example of phase change you might see in everyday life is when you boil water for noodles.



Heat transfers from the stove top to the pot via conduction. The energy imbalance in the body of water causes convectional heat transfer until the entire body reaches 100°C. From there all energy added to the system goes into breaking down intermolecular bonds and the water changes into steam.