Boğaziçi University

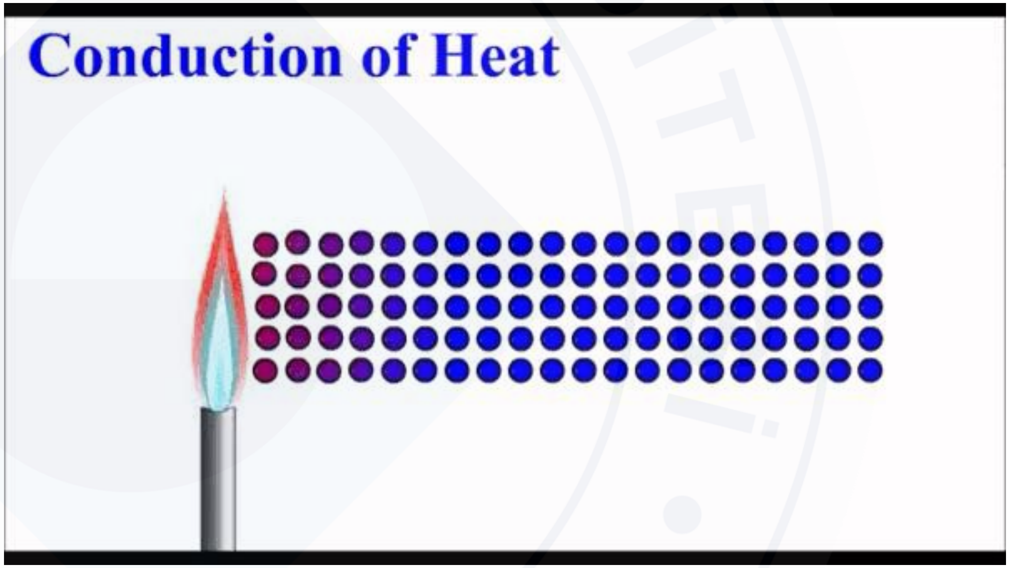
Introductory Phys Labs

SPECIFIC HEAT OF METALS AND HEAT OF FUSION OF ICE

PHYL 102

THEORY

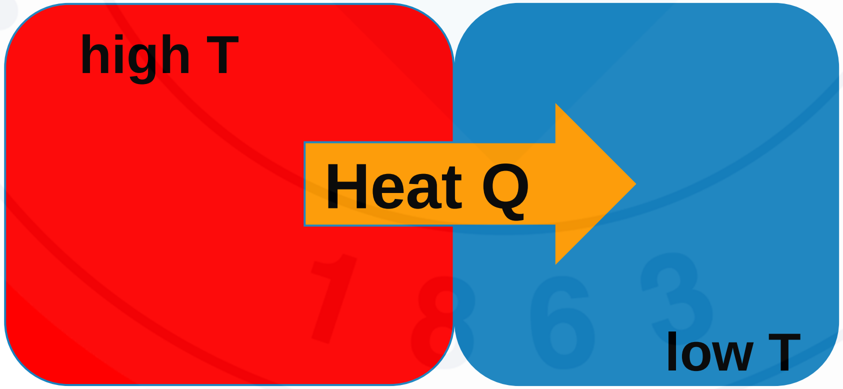
- **Energy can exist in different forms and can be transferred between objects in nature.**
- **The total energy is always conserved**
- **In thermodynamic processes, heat is the form of transferred energy between substances with different temperatures.**



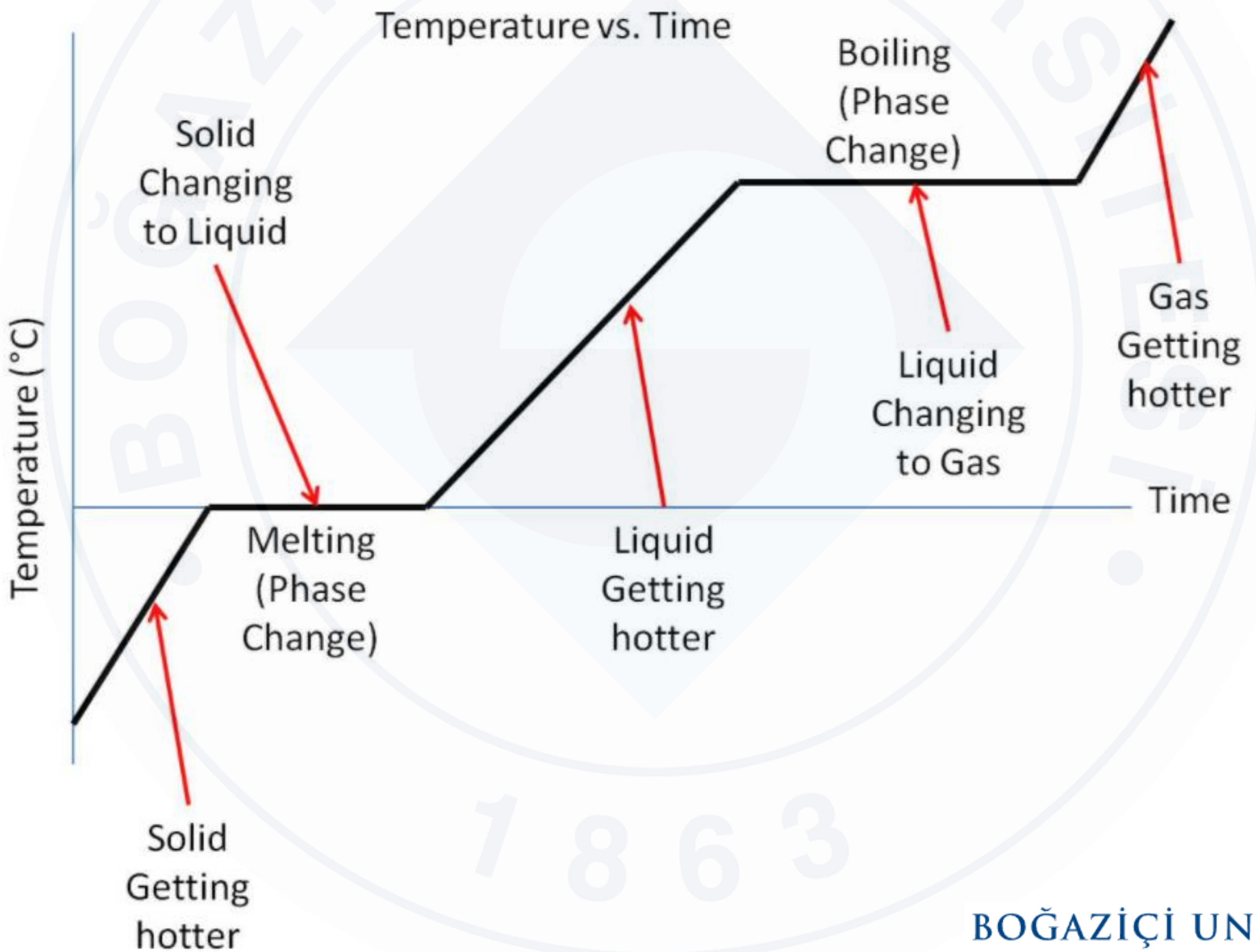
HEAT EXCHANGE

- **If you place two substances with different temperatures in contact, they exchange heat until they reach equal temperature.**
- **The substance with higher temperature loses heat and the one with lower temperature gains heat.**
- **The heat gained and lost are always equal.**

$$Q_{gained} = Q_{lost}$$



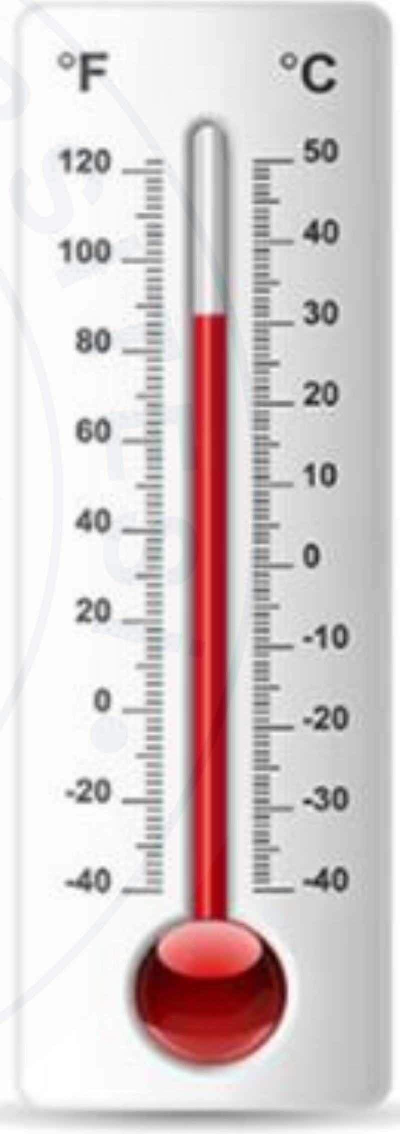
The heat transferred to/from a substance may change either the TEMPERATURE or PHASE of this substance.



Temperature Change:

For a substance with mass m, the heat Q changing its temperature by an amount of ΔT is calculated as

$$Q = mc\Delta T$$



- **The temperature change is measured with thermometer.**
- **c is the specific heat of the substance.**

SPECIFIC HEAT

Definition :

The specific heat is the amount of heat needed for a unit mass of substance to change its temperature by 1^{o}C.

- **Water has a specific heat of 1.00 cal/g^{o}C.**

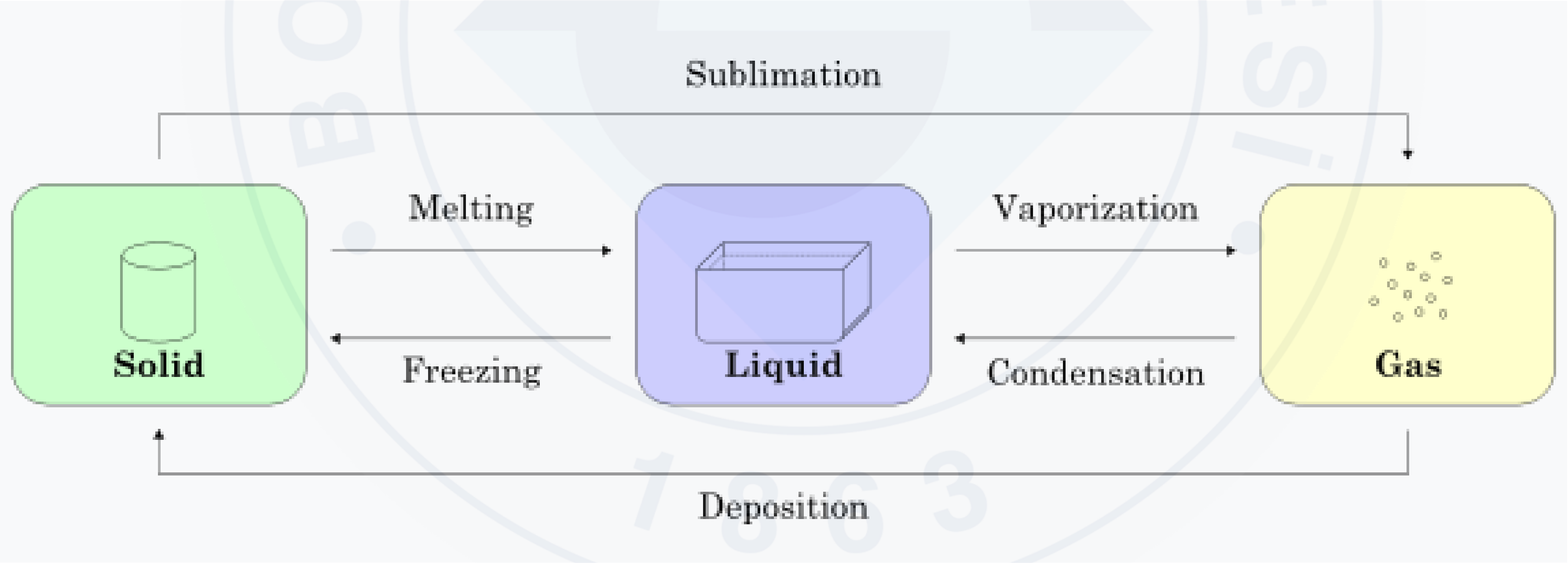
SPECIFIC HEAT OF METALS AND HEAT OF FUSION OF ICE

	Specific Heat	
Substance	(cal/g °C)	(J/g °C)
Water	1.00	4.18
Ethanol	0.58	2.4
Aluminum	0.22	0.92
Sand	0.19	0.79
Iron	0.11	0.46
Copper	0.093	0.39
Silver	0.057	0.24
Gold	0.031	0.13

- ❖ **Specific heat is a unique constant for every substance.**
- ❖ **It is an intrinsic property of a substance and does not depend on the size or shape of the substance.**
- ❖ **It is different for each state of matter. For example, specific heat of water (liquid) is 1.00 cal/g°C but specific heat of ice (solid) is 0.49 cal/g°C.**

Phase Transition:

- ❖ Phase transition is the change of the state of matter of a substance, e.g. melting of ice, boiling of water.
- ❖ The temperature is constant during the phase transition.

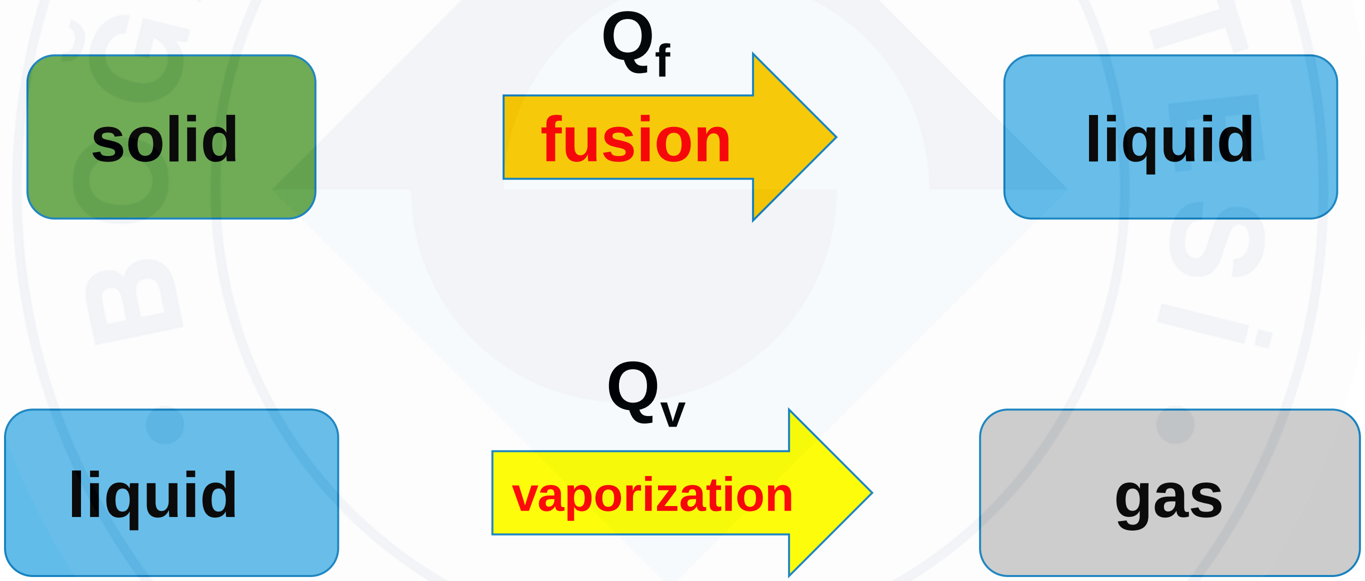


❖ For a substance with mass m, the heat Q changing its phase is calculated as

$$Q = mL$$

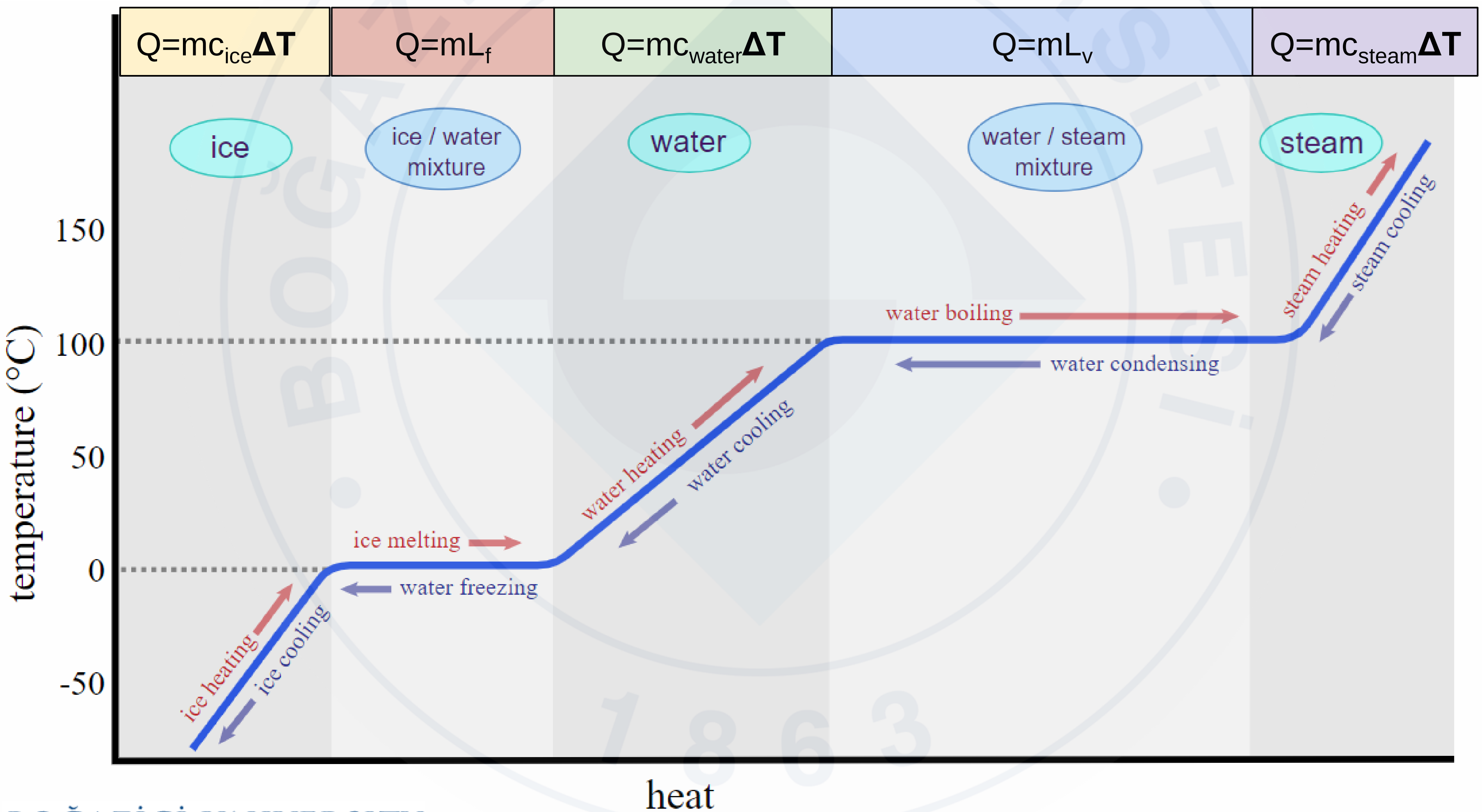
- L is the latent heat of the substance.
- The latent heat is the amount of heat needed for a unit mass of substance to change its phase.

- ★ L_f is the latent heat of fusion when the phase change is from solid to liquid.
- ★ L_v is the latent heat of vaporization when the phase change is from liquid to gas.



$$Q_f = mL_f \qquad Q_v = mL_v$$

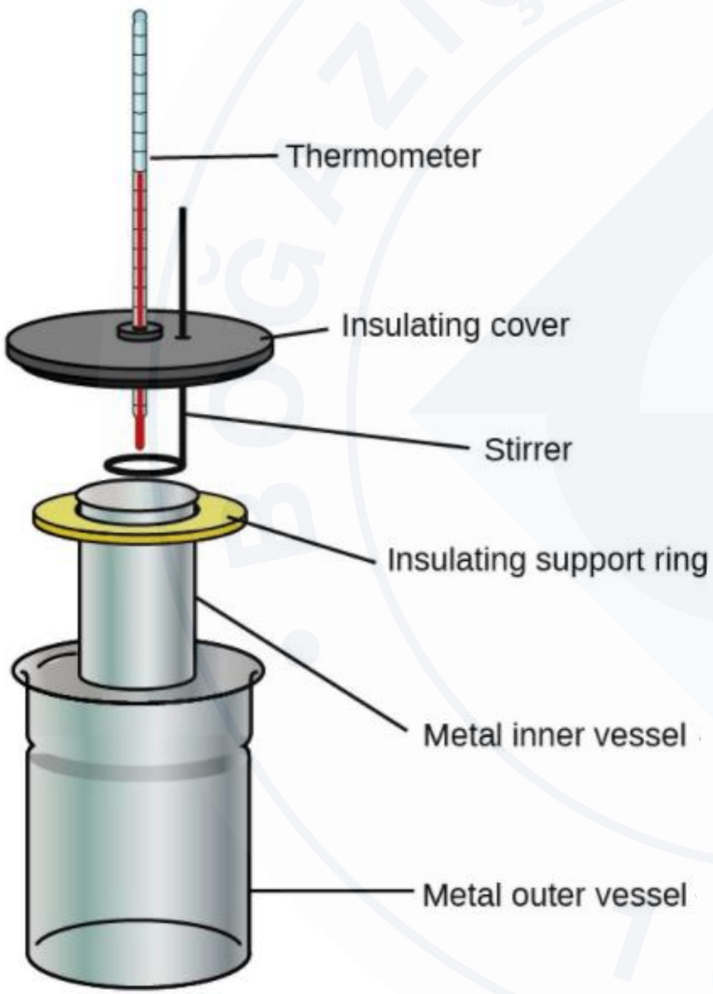
HEATING/COOLING CURVE OF WATER



APPARATUS

Apparatus: **Scale, Heater, Specimen in the Container, Thermometer, Water, Calorimeter with Temperature Sensor, Data Logger, Ice block**

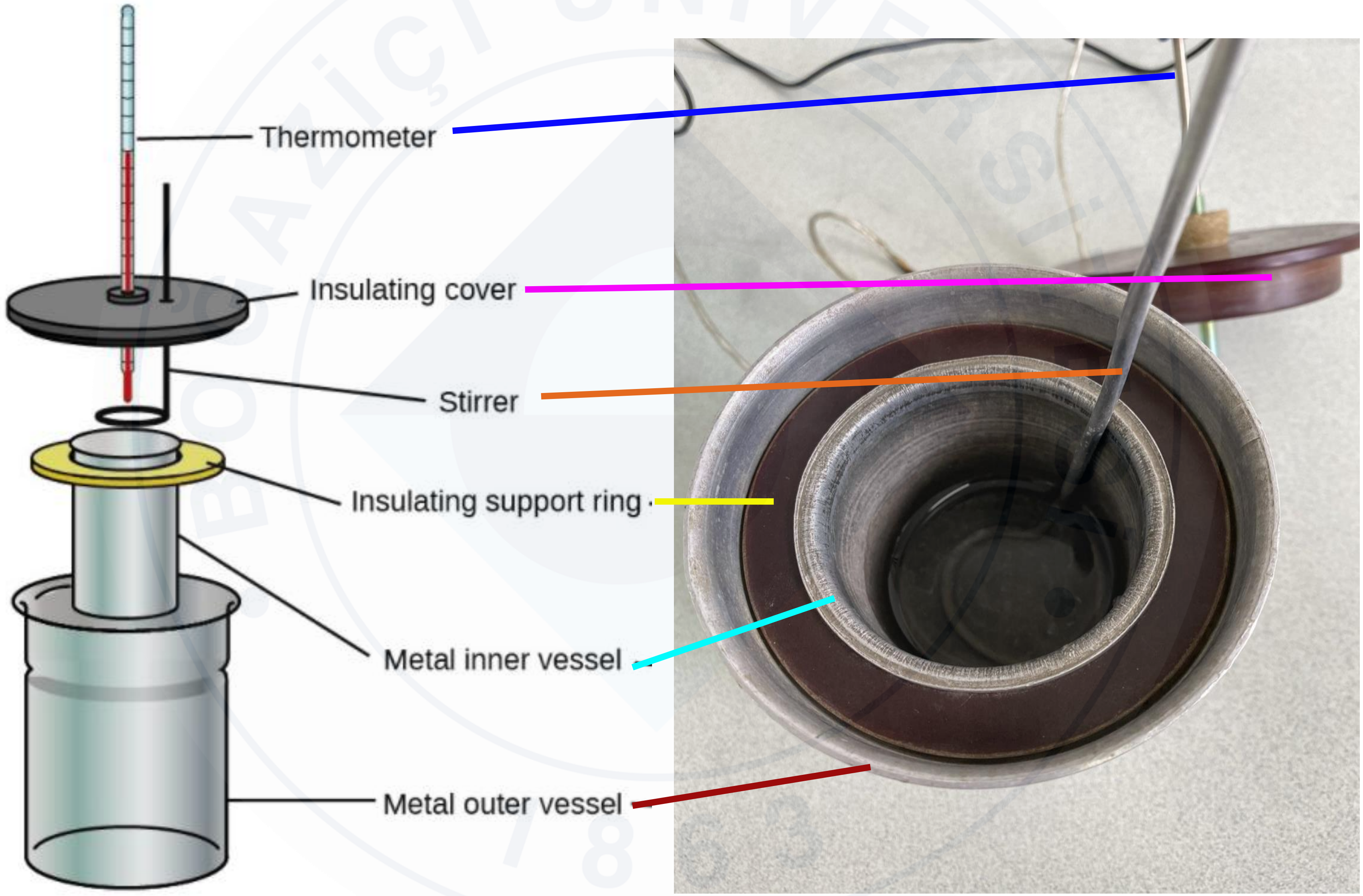
Calorimeter:



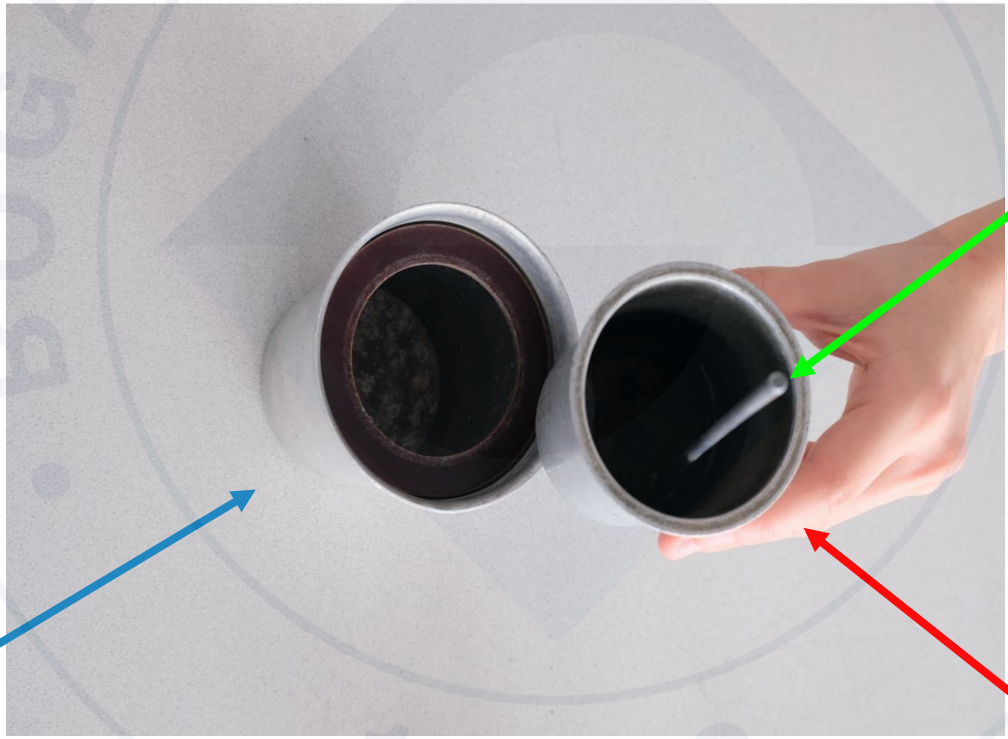
Heat is measured by calorimeter which is a vessel containing water of known mass and temperature.

- **A sample having a temperature higher than that of water is placed into the vessel.**
- **After the energy transfer ends, the final equilibrium temperature is measured.**
- **The transferred heat is calculated by applying the heat formula to the calorimeter.**

SPECIFIC HEAT OF METALS AND HEAT OF FUSION OF ICE

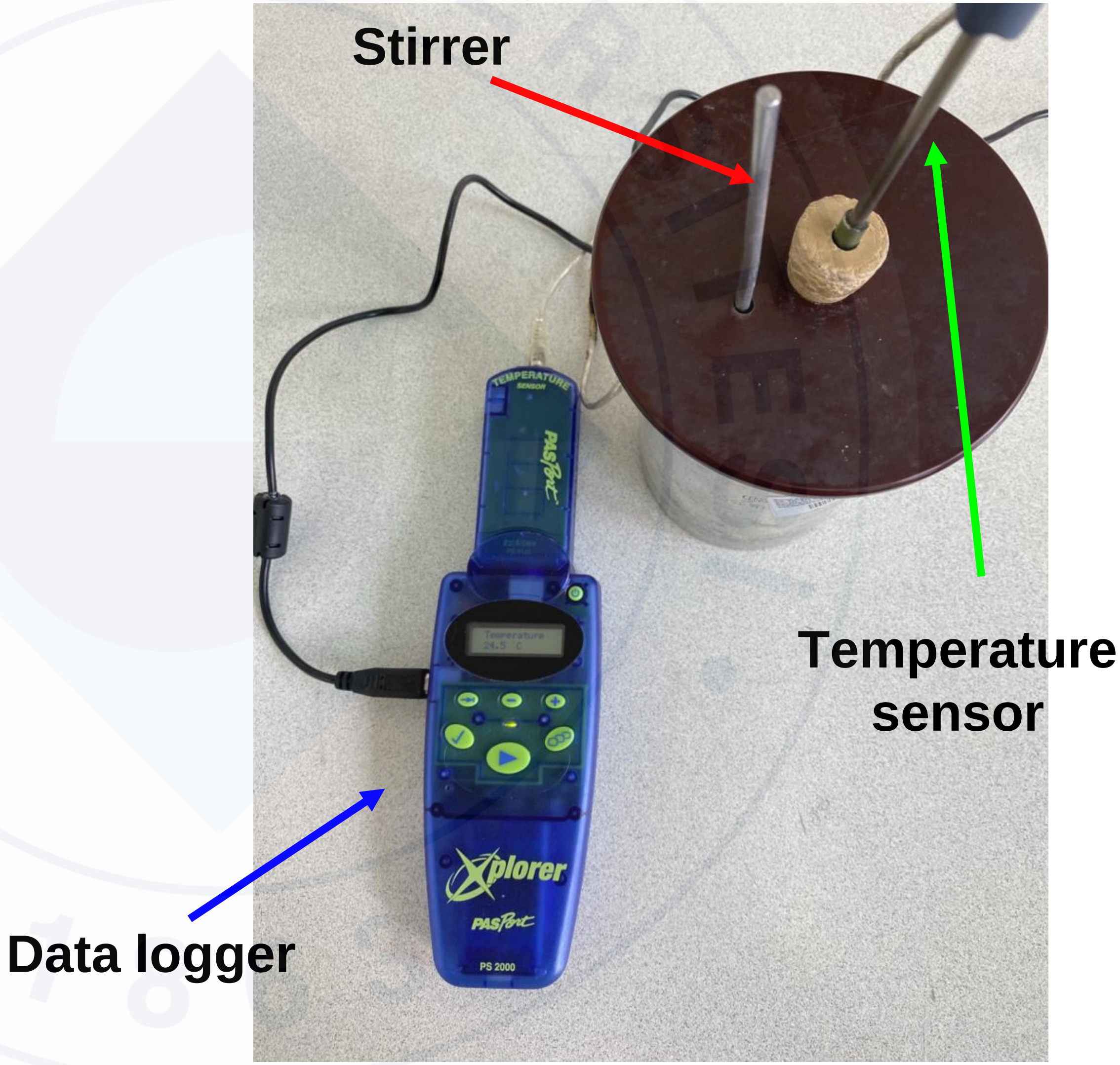


- ★ The outer vessel is for thermal isolation only.
- ★ The calorimeter is composed of inner vessel and stirrer.

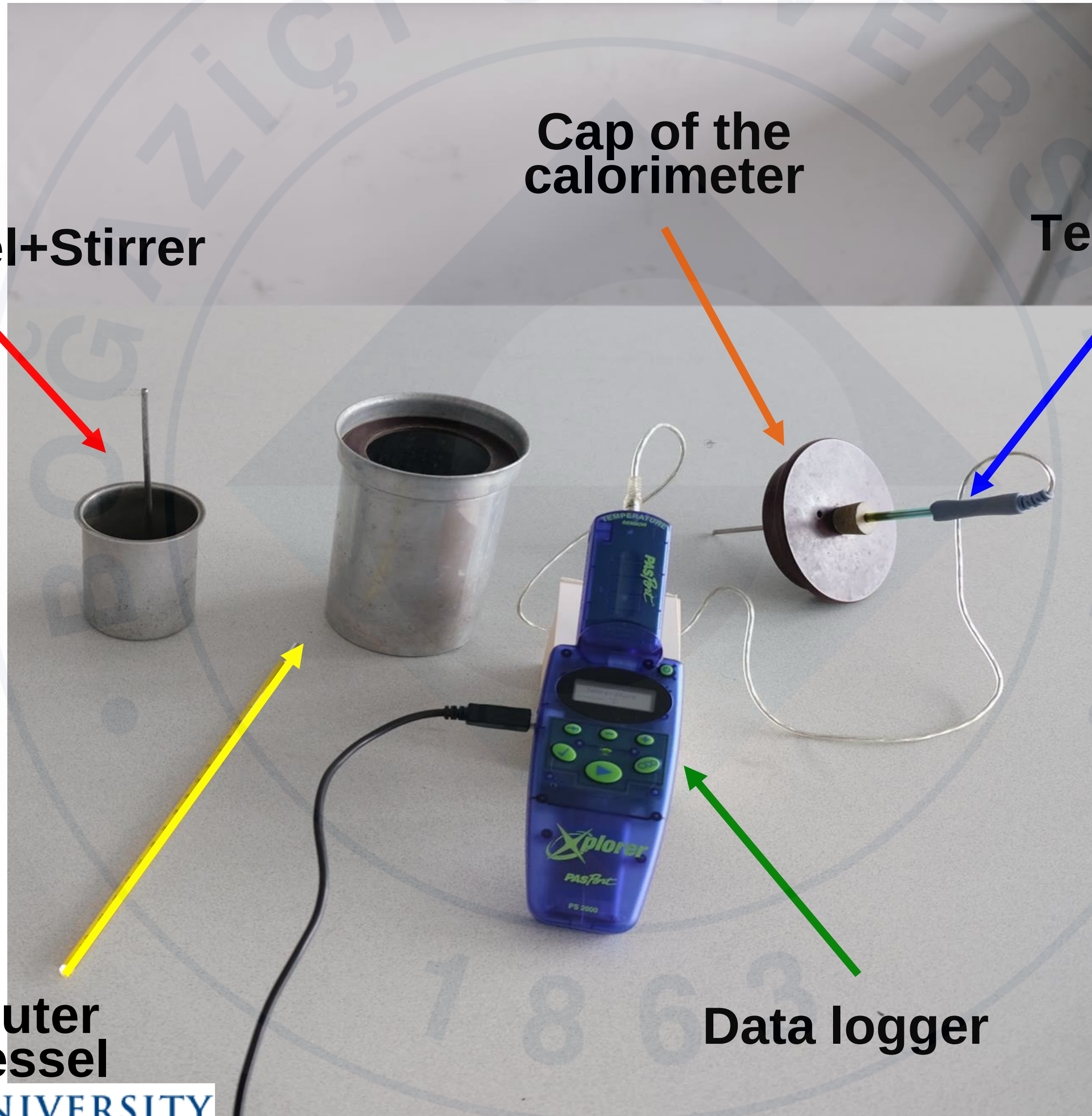


SPECIFIC HEAT OF METALS AND HEAT OF FUSION OF ICE

- **Temperature of the calorimeter is measured by the temperature sensor.**
- **The sensor is connected to the data logger.**
- **You can read the value of the temperature from the data logger.**



Calorimeter in details



The specimen (metal balls) is the sample whose specific heat will be determined in Part 1 of the experiment.

Container

Specimen (metal balls)

Cap of the Container

PART 1

Determination of the specific heat of the specimen

Specimen (metal balls) and water inside the calorimeter mixture

What to measure : Initial temperatures and masses of specimen, calorimeter and water, equilibrium temperature of the mixture

What to calculate : Heat gained and lost

Experimental findings : Specific heat of the specimen

Heating Specimen

- **Before preparing the mixture, the specimen with its container is heated inside the boiling water up to a high temperature.**
- **Follow the rise of the temperature on the thermometer. The maximum value is the <u>INITIAL</u> temperature of the <u>SPECIMEN</u>.**

Mixture

- The calorimeter is filled with water at room temperature. Their **INITIAL** temperature is read from **DATA LOGGER**.

- Then, the heated specimen (metal balls) is quickly poured into the calorimeter.

Mixture

- Since the specimen is at a higher temperature compared to the calorimeter and water, the value on the data logger increases until the mixture reaches equilibrium.

- The maximum value on the data logger is the EQUILIBRIUM temperature of the MIXTURE.

PHYSICAL CONSTANTS on page 123

(You will also find them in DataVideo.)

- **specific heat of water** $c_w = 1.00$ cal/g°C
- **specific heat of the calorimeter** $c_{cal} = 0.22$ cal/g°C
- **specific heat of ice** $c_{ice} = 0.49$ cal/g°C
- **heat of fusion of ice** $L_f = 79.72$ cal/g

SPECIFIC HEAT OF METALS AND HEAT OF FUSION OF ICE

Mass of the Calorimeter m_{cal} = ...

Mass of Water m_w = ...

Mass of the Specimen + container m_{s+con} = ...

Mass of the Specimen m_s = ...

Initial Temperature of the Calorimeter $t_{i\text{-}cal}$ = ...

Initial Temperature of Water $t_{i\text{-}w}$ = ...

Initial Temperature of the Specimen $t_{i\text{-}s}$ = ...

Equilibrium Temperature t_{1e} = ...

(fill in page 125)

Calculate mass of the specimen by subtracting mass of the container from their total mass.

This is the water inside the calorimeter, NOT the boiling water which heats the specimen!

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Physics Department

Specimen (metal balls) and water inside the calorimeter mixture

$$Q_{gained} = Q_{lost}$$

Calorimeter (cal)
Water (w)

Specimen (s)

$$m_{cal}c_{cal}(T_{eq} - T_{i\text{-}cal}) + m_w c_w(T_{eq} - T_{i\text{-}w}) = m_s c_s(T_{i\text{-}s} - T_{eq})$$

→ **T_i : initial temperature**

→ **T_{eq} : equilibrium temperature**

PART 2

Measurement of the mass of the ice block

Adding an ice block to the mixture in Part 1

What to measure : Initial temperature of ice block, initial temperature of the mixture in Part 1, equilibrium temperature of the final mixture including ice block

What to calculate : Heat gained and lost

Experimental findings : Mass of the ice block

Mixture

- An ice block is dropped into the water-specimen-calorimeter mixture of Part 1.
- Since this mixture is at a higher temperature compared to the ice block (below 0ºC), the value on the data logger decreases until the mixture reaches equilibrium.
- The minimum value on the data logger is the EQUILIBRIUM temperature of the MIXTURE.

Initial Temperature of Ice $t_{\text{i-ice}}$ = ...

Initial temperature of the ice block is written on the fridge.

Initial Temperature of the Calorimeter, Water and the Specimen $t_{\text{i-cal + contents}}$ = ...

→ *This is different from the equilibrium temperature of Part 1!*

Equilibrium Temperature t_{2e} = ...

(fill in page 127)

Adding an ice block to the mixture in Part 1

$$Q_{gained} = Q_{lost}$$

Ice block

Calorimeter (cal)
Water (w)
Specimen (s)

★ **ice block raises to 0°C, melts at 0°C and raises to T_{eq}**

$$m_{ice}c_{ice}(0-T_{i\text{-}ice})+m_{ice}L_f+m_{ice}c_w(T_{eq}-0)=(m_{cal}c_{cal}+m_wc_w+m_sc_s)(T_{i\text{-}cal,w,s}-T_{eq})$$

- ➔ **T_i : initial temperature**
- ➔ **T_{eq} : equilibrium temperature**

USE SYMBOLS ONLY, NO NUMERICAL EVALUATION!

Use

Q_{gained}=Q_{lost}

formula of

Part 1.

(fill in page 127)

For PARTS-1: (NO NUMERICAL EVALUATION)

Heat Lost: ....

....

Heat Gained: ....

....

Specific Heat of the Specimen: c_s = ...

USE SYMBOLS ONLY, NO NUMERICAL EVALUATION!

For PART-2: (NO NUMERICAL EVALUATION)

Use $Q_{gained}=Q_{lost}$ formula of **Part 2.**

Heat Lost: . . . .

. . . .

Heat Gained: . . . .

. . . .

(fill in page 129)

Mass of Ice: $m_{\text{ice-EV}} =$ . . . .

NUMERICAL CALCULATION

Specific Heat
of the Specimen c_s = ...

....

Total Mass m_{total} = ...

Total mass is in DataVideo.

Experimental Value of the
Mass of Ice $m_{ice\text{-}EV}$ = ...

....

Measured Value of the
Mass of Ice $m_{ice\text{-}MV}$ = ...

Calculate from the total mass!

Measured value=Theoretical value

....

% Error for the Mass of Ice:...................................

(fill in page 130)

(fill in pages 130 and 131)

Dimensional analysis for the Specific Heat:. . . . .

QUESTIONS

(Answer ONE of the questions)