(1H.L2.1) Familiarize Stage

Thursday, March 29, 2018 8:34 PM

1st Law and Heat (1H)

Familiarize Stage:

Pre-lecture 2: Specific Heat, Phase Transformations, Calorimetry

Reading
1. Read

Lecture Videos
1. Watch

Example Problems
1. Watch

Simulations
1. Sim

Other Suggested Content
1. Check out

Practice
1. Try

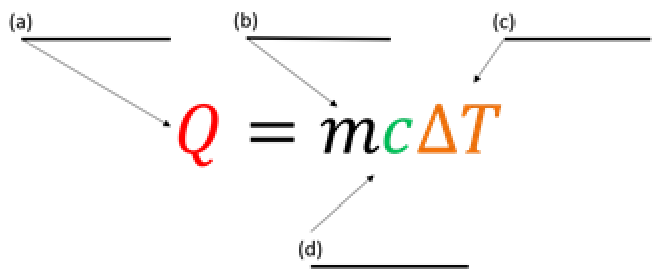
Homework

1H.L2.1-01

Description: Infographic quiz heat equation - label matching

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Match each term in the equation with the correct description from the following list.
(1) Mass, (2) Change in temperature, (3) Heat, (4) Specific heat



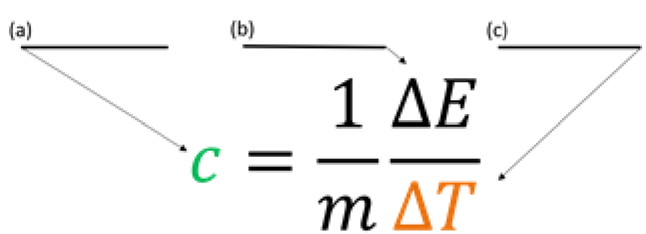
Answer: (a) Heat, (b) Mass, (c) Change in temperature, (d) Specific heat

1H.L2.1-02

Description: Infographic quiz specific heat - label matching

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Match each term in the equation with the correct description from the following list.
(1) Change in temperature, (2) Change in energy, (3) Specific heat



Answer: (a) Specific heat, (b) Change in energy, (c) Change in temperature

1H.L2.1-03

Description: Understanding specific heat

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: What is specific heat?

(1) The specific heat is the amount of heat needed to change the temperature of 1 kg of a substance by 1∘ F
(2) The specific heat is the amount of heat needed to raise the temperature of 1 kg of a substance by 10∘ C
(3) The specific heat is the amount of heat needed to lower the temperature of 1 kg of a substance by 1∘ F
(4) The specific heat is the amount of heat needed to raise the temperature of 1 kg of a substance by 1∘ C.

Answer: (4)

1H.L2.1-04

Description: Understanding specific heat

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: What does specific heat depend upon?

(1) Specific heat depends upon the volume of the substance and its phase.
(2) Specific heat depends upon the physical properties of the substance and its phase.
(3) Specific heat depends upon the mass of the substance and its phase.
(4) Specific heat depends upon the mass of the substance and its volume.

Answer: (2)

1H.L2.1-05

Description: Assumptions during a calorimetry experiment

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: An unknown hot metal object is placed in cool water and the two are allowed to reach equilibrium. In a calorimetry experiment the temperature changes and masses of the two substances can be used to determine the specific heat of the unknown metal. What is the main assumption in this calorimetry experiment?

(1) No work or heat transfer occurs on the combined (water + metal) system
(2) No work occurs on the combined (water + metal) system but heat is transferred into or out of the system
(3) The net change in heat transfers of the individual metal and water systems is zero
(4) The net change in heat transfers of the individual metal and water systems is not zero

Answer: (1), (3)

1H.L2.1-06

Description: understanding heat transfer and phase change

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: What is latent heat?

(1) It is the heat that must transfer energy to or from a system in order to cause a mass change with a slight change in the temperature of the system.
(2) It is the heat that must transfer energy to or from a system in order to cause a mass change without a temperature change in the system.
(3) It is the heat that must transfer energy to or from a system in order to cause a phase change with a slight change in the temperature of the system.
(4) It is the heat that must transfer energy to or from a system in order to cause a phase change without a temperature change in the system.

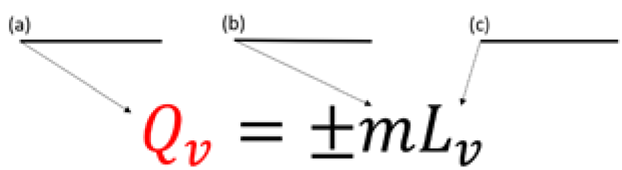
Answer: (4)

1H.L2.1-07

Description: Infographic quiz transformation vaporization - label matching

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Match each term in the equation with the correct description from the following list. (1) Latent heat of vaporization, (2) Mass, (3) Heat of vaporization



$$Q_v = \pm m L_v$$

Answer: (a) Heat of vaporization, (b) Mass, (c) Latent heat of vaporization

1H.L2.1-08

Description: Infographic quiz transformation fusion - label matching

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Match each term in the equation with the correct description from the following list. (1) Mass, (2) Latent heat of fusion, (3) Heat of fusion

(a) ________ (b) ________ (c) ________

$$Q_f = \pm m L_f$$

Answer: (a) Heat of fusion, (b) Mass, (c) Latent heat of fusion

1H.L2.1-09

Description: Heat of fusion versus Heat of vaporization

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: What is the difference between heat of vaporization and heat of fusion?

(1) Heat of fusion is a measure of energy transferred during the transition from a solid to a liquid (or vice versa) while heat of vaporization is a measure of energy transferred during the transition from a liquid to a gas (or vice versa).
(2) Heat of fusion is a measure of energy transferred during the transition from a liquid to a gas

(or vice versa) while heat of vaporization is a measure of energy transferred during the transition from a solid to a liquid (or vice versa).
(3) There is no difference between the two

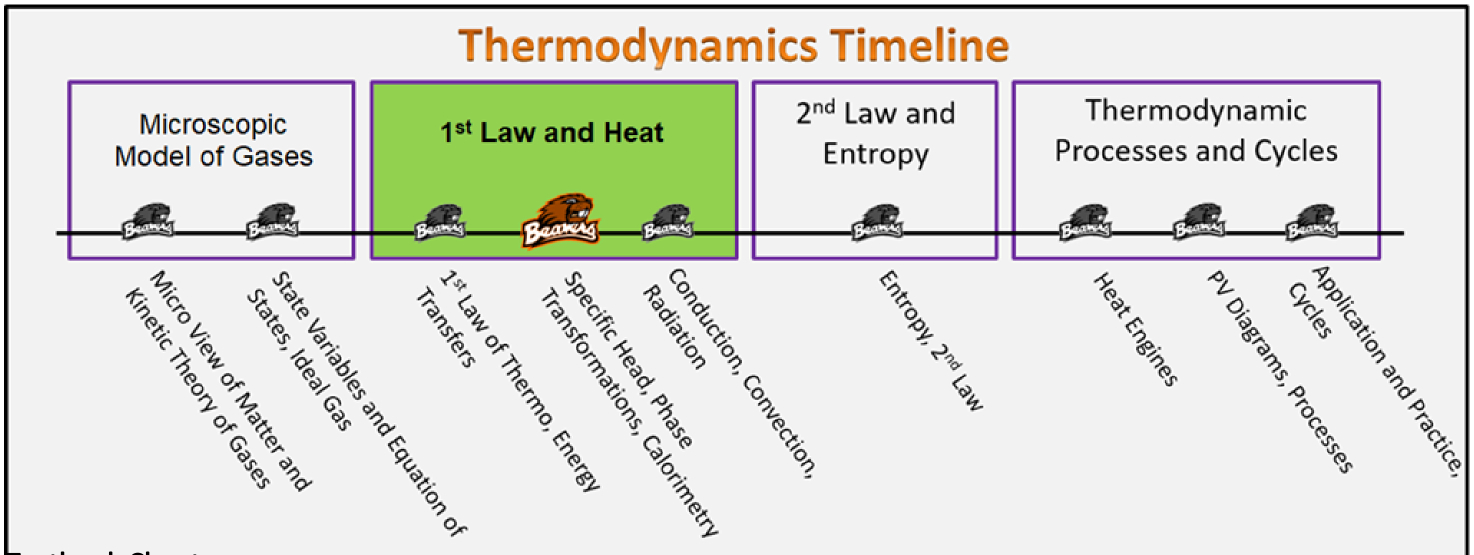
Answer: (1)

(1H.L2.2.sols) Foundation Stage Solutions

Tuesday, January 29, 2019 10:07 AM

1st Law and Heat
Foundation Stage (1H.L2.2)

Lecture 2
Specific Heat, Phase Transformations, Calorimetry



Textbook Chapters (* Calculus version)

- **BoxSand** :: KC videos (1st Law of Thermodynamics)
- **Knight** (College Physics : A strategic approach 3rd) ::
- ***Knight** (Physics for Scientists and Engineers 4th) ::
- **Giancoli** (Physics Principles with Applications 7th) ::

Warm up

1H.L2.2-01:

Description:

Learning Objectives: [?] - Can you identify the objectives from the previous lecture, and this lecture, that this question is relevant to?

Problem Statement: Consider a two spherical objects of equal mass that are resting on a table in thermal equilibrium with the environment; one object is made of Adamantium and the other of Kryptonite. The first law of thermodynamics tells us that we can increase the thermal energy of each object by doing work on it or via heat. During an experiment during which Dr. Strange increased the temperature of each object by 1 K, he observed that it required different amounts of thermal energy to increase the temperature by the same amount. Discuss with your neighbors a possible explanation for Dr. Strange's observation.

Selected Learning Objectives

1. Coming soon to a lecture template near you.

Key Terms

- Temperature
- Thermal energy
- Thermodynamic equilibrium
- Specific heat
- Solid, liquid, and gas phases
- Heat of transformation (vaporization, fusion)
- Melting point
- Boiling temperature

Key Equations

Specific Heat, Phase Transformations, Calorimetry

Specific heat is essentially the amount of energy necessary to raise the temperature of a certain amount of a substance. Specific heat is usually used for solids and liquids (we explored how the temperature of gases changes last week). If no external work is being done on the substance, then the change in energy is provided by heat.

$$C = \frac{1}{m}\frac{\Delta E}{\Delta T} = \frac{1}{m}\frac{Q}{\Delta T}$$

The three phases we will study are solid, liquid, and gas. A common example of one substance exhibiting these phases is (water) ice, liquid water, and steam. When a solid reaches the temperature at which it begins to melt into a liquid, additional energy is necessary to break apart the bonds of the lattice (atoms in a solid are arranged in a rigid repeating pattern called a lattice). Therefore additional energy added to the solid will not raise its temperature. The amount of energy necessary to convert a solid into a liquid (per amount of substance) is referred to as the "latent heat of fusion" and is given the symbol L_f. The total energy necessary to convert a given amount of substance is then given by:

$$Q_f = \pm m L_f$$

Similarly the amount of energy necessary to convert a liquid into a gas (or a gas into a liquid) is called the "latent heat of vaporization."

$$Q_v = \pm m L_v$$

The sign of the necessary energy depends on whether you are transforming from solid to liquid (+), liquid to solid (-), liquid to gas (+), or gas to liquid (-).

Key Concepts

○

Questions

Act I: Specific Heat

1H.L2.2-02:

Description: Non-quantitative. (3 minutes)

Learning Objectives: [?]

Problem Statement: For which of the following situations is $\Delta E^{Th} = Q = mC\,\Delta T$ the correct expression to describe the change in temperature due to thermal energy transfer?

(1) Brakes stopping your car.

(2) Your refrigerator cooling your Jell-O.

(3) Heating up some leftovers in your microwave.

(4) Rubbing your hands together to warm them up on a cold day.

1H.L2.2-03:

Description: Temperature change due to thermal energy change in a solid. (3 minutes)

Learning Objectives: [?]

Problem Statement: How much energy must be removed from a 200 g block of ice to cool it from 0°C to -30°C? The specific heat of ice is 2090 J/(kg K).

(1) 10,500 J
(2) 12,500 J
(3) 10,500,000 J
(4) 12,540,000 J
(5) 14,520,000 J

$$\Delta E^{TH} = M_I C_I \Delta T_I$$

$$= (0.20\,kg)\left(2090 \frac{J}{kgK}\right)(-30\,°C - 0\,°C)$$

$$\Delta E^{TH} = -12540\,J$$

↑ REMOVED

1H.L2.2-04:

Description: (3 minutes)

M=CONSTANT

Learning Objectives: [?]

Problem Statement: 100 g of each of the following materials is heated. Each material gets the same amount of thermal energy. Which material will increase in temperature the most?

(1) Copper
(2) Magnesium
(3) Aluminum

Material	Density	Melting Point	c	Conductivity
Copper	8.96 g/cc	1085 °C	385 J/kg°C	401 W/m°C
Magnesium	1.74 g/cc	650 °C	1020 J/kg°C	156 W/m°C
Aluminum	2.70 g/cc	660 °C	897J/kg°C	237 W/m°C

$$\Delta E^{TH} = mc\Delta T$$

$$\Delta T = \left(\frac{\Delta E^{TH}}{m}\right)\frac{1}{c}$$

CONSTANT

$$\text{so } \Delta T \propto \frac{1}{c}$$

Act II: Phase Transformations

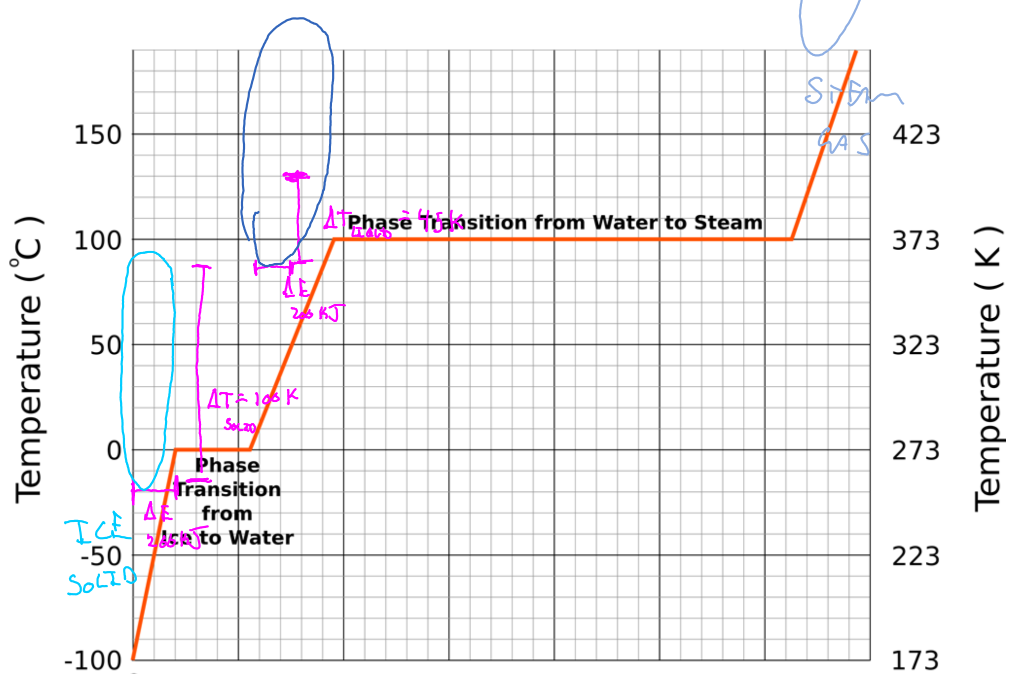
1H.L2.2-05:

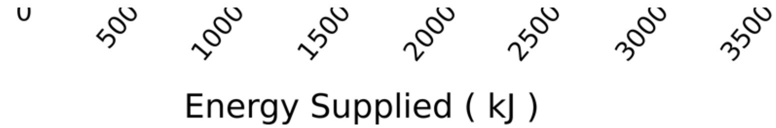
Description: (3 minutes)

Learning Objectives: [?]

Problem Statement: The graph shows the temperature as a function of energy supplied to 1 kg of H_2O. If 200 kJ of energy is added, will the temperature rise more during the solid or liquid phase?

(1) Solid
(2) Liquid





$C = \frac{1}{m} \frac{\Delta E^{th}}{\Delta T}$ $C = \frac{1}{m} \cdot \frac{1}{SLOPE}$ $C \propto \frac{1}{SLOPE}$

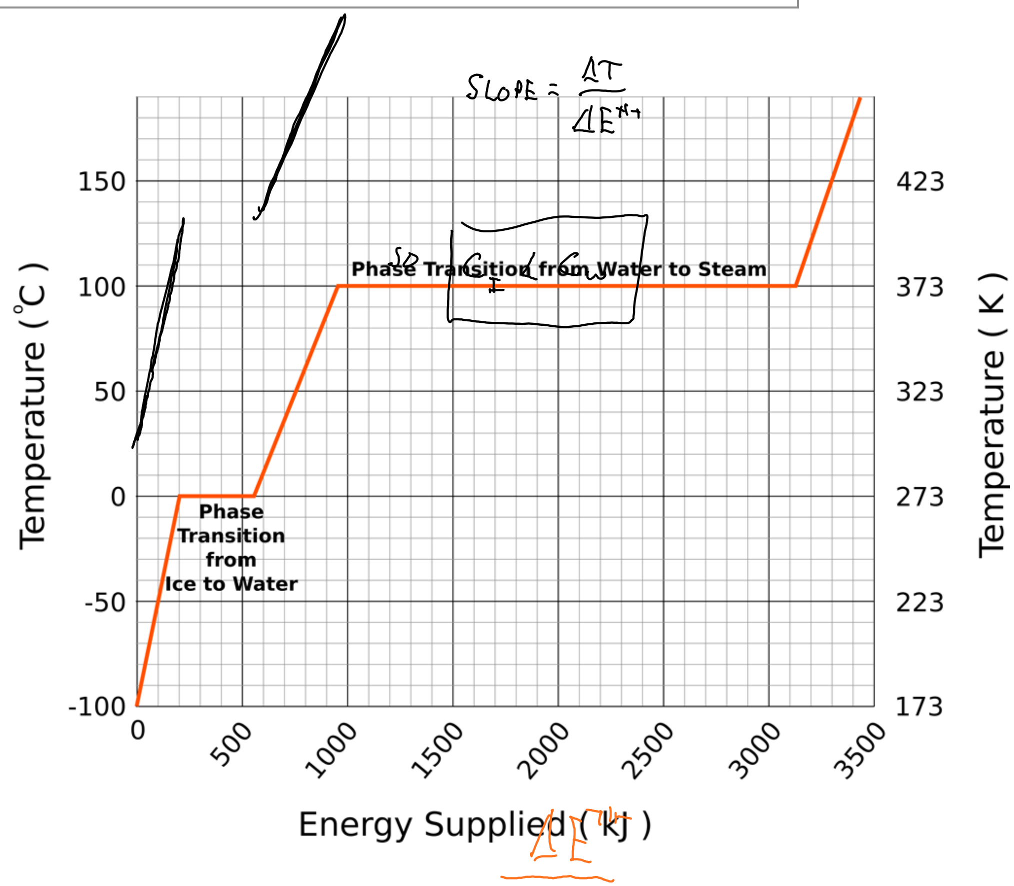
1H.L2.2-06:

Description: (3 minutes)

Learning Objectives: [?]

Problem Statement: Which has a larger specific heat, the solid or liquid phase?

(1) Solid
(2) Liquid



1H.L2.2-07:

Description: (3 minutes)

Learning Objectives: [?]

Problem Statement: H_2O is initially at -100 °C. It is put in a microwave that deposits energy at a constant rate. Which is larger?

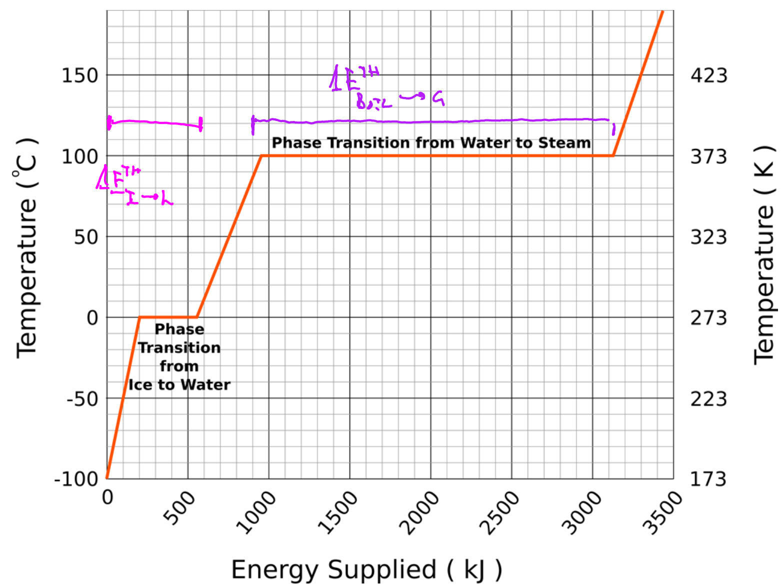
(1) The time interval between the start and when the water is entirely liquid.

(2) The time interval between when the water starts to boil and when it is entirely gas.

(3) Both are the same.

$\Delta t_{Boil \to G} = \frac{3000}{500} \Delta t_{I \to L}$

$\Delta t_{Boil \to G} = 6 \Delta t_{I \to L}$



1H.L2.2-08:

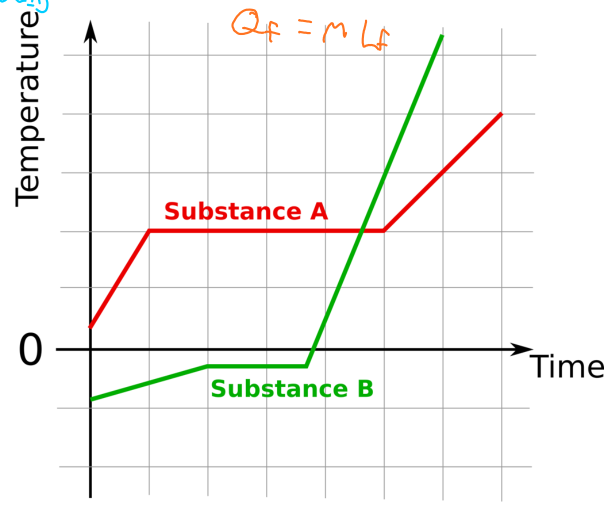
Description: For at-home practice (3 minutes)

Learning Objectives: [?]

Problem Statement: Samples of two pure substances are heated at a constant rate, and their temperature as a function of time is recorded. Both substances started as solids and melted. The mass of the two samples is the same.

(a) The latent heat of fusion of substance **A** is ______ the latent heat of fusion of substance **B**.

(1) greater than
(2) less than
(3) equal to



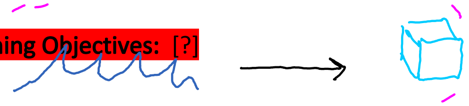
(b) The melting point of substance **A** is ________ the melting point of substance **B**.

(1) greater than
(2) less than
(3) equal to

1H.L2.2-09:

Description: (3 minutes)

Learning Objectives: [?]



Problem Statement: How much energy must be removed from 200 g of liquid water to cool it from 0 °C to -30 °C?

ΔE^{th}

(1) 32,500 J
(2) 12,500 J
(3) 65,310 J
(4) 81,554 J
(5) 79,100 J

$$\Delta E^{th} = -m L_f + m c_{ice} \Delta T$$

$$= -(0.20\,kg)(3.33\times10^5\,J/kg) + (0.20\,kg)(2090\,J/kgK)(-30\,°C - 0\,°C)$$

$$= -66600\,J - 12540\,J$$

$$\Delta E^{th} = -79140\,J$$

↑ REMOVED

c_{ice} = 2090 J/(kg·K)
L_f = 3.33 x 10^5 J/kg
L_v = 22.6 x 10^5 J/kg

NEEDS TO BE ISOLATED/INSULATED SYSTEM

Act III: Calorimetry

(1) (2)

1H.L2.2-10:

Description: (3 minutes)

Learning Objectives: [?]

Q IN OR OUT

NO Q IN OR OUT

Problem Statement: For which one of the following systems would a Calorimetry analysis be appropriate?

(1) A cube of ice dropped into coffee in an aluminum cup.

(2) A cube of ice dropped into coffee in an insulated thermos.

ASSUME INSULATED

1H.L2.2-11:

Description: (3 minutes)

Learning Objectives: [?]

Q

ASSUME NO Q IN OR OUT

$$C_L M_L \Delta T_L + C_w M_w \Delta T_w = 0$$

Problem Statement: Hot lead is put into water in a Styrofoam cup. The lead and water come to equilibrium without any steam being produced.

So $\Sigma Q = 0$

$Q_L + Q_W = 0$

(a) Which of the following statements are true?

(1) The water loses/gains the same amount of temperature as the lead gains/loses.

$Q_L = -Q_W$

(2) The water loses/gains the same amount of energy as the lead gains/loses.

(b) Which of the following equations would best describe the situation?

(1) $C_L m_L \Delta T_L + C_W m_W \Delta T_W = 0$

(2) $C_L m_L \Delta T_L - C_W m_W \Delta T_W = 0$

$C_L M_L \Delta T_L + C_W M_W \Delta T_W = 0$

$(128)(0.1)(T_f - 100) + (4186)(0.5)(T_f - 20) = 0$

⋮

$T_f \approx 20.5\,^\circ C$

(c) Suppose the lead is 100 grams and initially 100 °C before being placed into 0.50 kg of water initially at 20 °C in a Styrofoam cup. Calculate the final temperature.

c_L = 128 J/kg K
c_W = 4186 J/kg K

1H.L2.2-12:

Description: (3 minutes)

Learning Objectives: [?]

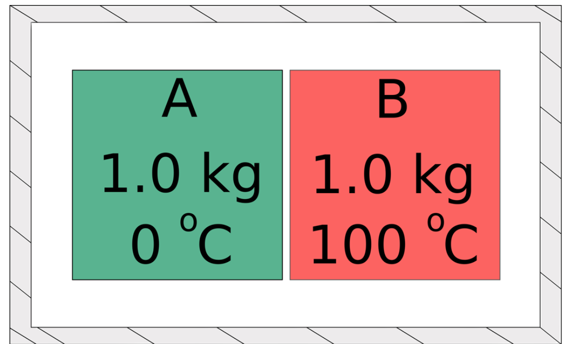
Problem Statement: Objects **A** and **B** are brought into close thermal contact with each other, but they are well isolated from their surroundings. Initially T_A = 0 °C and T_B = 100 °C. The specific heat of **A** is more than the specific heat of **B**. The two objects will soon reach a common final temperature T_f. The final temperature is?

(1) $T_f > 50$ °C

(2) $T_f < 50$ °C

(3) $T_f = 50$ °C

NO ΔE^{TH} IN OR OUT



$C_A > C_B$

SO $\sum \Delta E^{TH} = 0$

OR $\Delta E^{TH}_A = -\Delta E^{TH}_B$

$M_A C_A \Delta T_A = -M_B C_B \Delta T_B$

$$\frac{|\Delta T_B|}{|\Delta T_A|} = \frac{C_A}{C_B} \rightarrow \text{SO } |\Delta T_B| > |\Delta T_A|$$

B LOSES MORE T THAN A GAINS SO

$T_F < 50$ °C

Conceptual questions for discussion

a. .

Hints

1H.L2.2-01: No hints.

1H.L2.2-02: No hints.

1H.L2.2-03: No hints.

1H.L2.2-04: No hints.

1H.L2.2-05: No hints.

1H.L2.2-06: No hints.

1H.L2.2-07: No hints.

1H.L2.2-08: No hints.

1H.L2.2-09: No hints.

1H.L2.2-10: No hints.

1H.L2.2-11: No hints.

1H.L2.2-12: No hints.

(1H.L2.3) Practice Stage

Thursday, March 29, 2018 8:34 PM

1st Law and Heat (1H)

Practice Stage:

Post-lecture 2: Specific Heat, Phase Transformations, Calorimetry

Reading
1. none

Lecture Videos
1. none

Example Problems
1. none

Simulations
1. none

Other Suggested Content
1. none

Practice
1. none

Homework

1H.L2.3-01a

Description: Calculate volume in SI.

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: A typical ice tray can make 14 ice cubes. The dimensions for each bine are the following: L = 1.50 inches, W = 1.25 inches, H = 1.00 inches. We eventually wish to determine how much thermal energy must be removed by a freezer to make ice at 0 degrees Celsius if the initial temperature was 10 degrees Celsius. What is the volume of the water in the ice tray in SI units?

(1) 1.875 in^3
(2) 3.07 x 10^{-5} m^3
(3) 4.30 x 10^{-4} m^3
(4) 26.25 in^3

Answer: (3)

1H.L2.3-01b

Description: Calculate mass given volume and density.

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: A typical ice tray can make 14 ice cubes. The dimensions for each bine are the following: L = 1.50 inches, W = 1.25 inches, H = 1.00 inches. We eventually wish to determine how much thermal energy must be removed by a freezer to make ice at 0 degrees Celsius if the initial temperature was 10 degrees Celsius. The density of water at these temperatures is about 1000 kg/m^3. What is mass of the water in the ice tray in SI units?

(1) 0.430 kg
(2) 0.2625 kg

(3) 0.307 kg
(4) 0.1875 kg

Answer: (1)

1H.L2.3-01c

Description: Thermal energy and specific heat calculation.

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: A typical ice tray can make 14 ice cubes. The dimensions for each bine are the following: L = 1.50 inches, W = 1.25 inches, H = 1.00 inches. How much thermal energy must be removed by a freezer to make ice at 0 degrees Celsius if the initial temperature was 10 degrees Celsius? Assume the tray has a very very low specific heat.

(1) 972 J
(2) 143000 J
(3) 4200 J
(4) 420000 J

Answer: (2)

1H.L2.3-01d

Description: Unit conversion.

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: How many joules is 1 kW·hr (kilowatt·hour)?

(1) 1 J
(2) 36 J
(3) 360 J
(4) 3600000 J

Answer: (4)

1H.L2.3-01e

Description: Unit conversion.

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: If electricity costs 15 cents per kWhr, how much money does it cost to freeze the ice in the tray? Assume that the freezer is 100% efficient.

(1) about 42 cents
(2) about 2 cents
(3) about 1 cent
(4) about 1/2 a cent

Answer: (4)

1H.L2.3-01f

Description: Unit conversion.

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: If the freezer is 50% efficient, how much does it cost now?

(1) about 42 cents
(2) about 2 cents
(3) about 1 cent
(4) about 1/2 a cent

Answer: (3)

1H.L2.3-02

Description: Calorimetry.

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: The specific heat of liquid mercury is 140 J/kg·K. When 1.00 kg of solid mercury at its melting point of -39.0 C is placed in a 0.50 kg aluminum calorimeter filled with 1.20 kg of water at 20 C, the final temperature of the combination is found to be 16.5 C. What is the heat of fusion of mercury in J/kg?

(1) 6200 J/kg

(2) 19200 J/kg
(3) 11400 J/kg
(4) 9830 J/kg

Answer: (3)