5. Heat

Let us Assess

1. Question

What are the following temperatures in the Celsius scale?

(a) 491.67° F

(b) 673 K

Answer

(a) The formula to convert °F to °C is:

$$F^\circ = \frac{9}{5}C^\circ + 32$$

$\Rightarrow 491.67 - 32 = \frac{9}{5}C^\circ$

$\Rightarrow 459.67 = \frac{9}{5}C^\circ$

$$\Rightarrow C^0 = 459.67 \times \frac{5}{9} = 255.4^\circ C$$

491.67° F $\rightarrow$ 255.4°C

(b) To convert from kelvin scale to Celsius scale we use K = 273 + °C

673 K $\rightarrow$ 400°C

2. Question

Water containing propylene glycol is used as coolant in engines.

(a) Which property of water makes it a coolant?

(b) What is the advantage of adding propylene glycol to the water used as coolant?

Answer

(a) Water has a high specific heat capacity which is defined as amount of heat one gram of a substance must absorb or lose to change its temperature by one degree Celsius. This property is caused due the presence of hydrogen bonding among water molecules. The above property makes water as a e× cellent coolant as it takes long time to heat and cool water. This is the reason why land cools & heats faster than water.

Moreover, it is non-to× ic and non-poisonous and easily & cheaply available which gives it a superior advantage over other products.

(b) Adding propylene glycol (anti-freeze) to the water lowers the freezing temperature of the water due to Freezing point depression (is the decrease of the freezing point of a solvent on addition of a non-volatile solute). For e× ample, Sea Water (water + Salt) has a freezing temperature below 0°C and boiling point above 100°C. Because of it water can withstand cold temperature without freezing. Moreover, it also increases the boiling temperature of water.

3. Question

A wet cloth is placed on the forehead of a person having fever.

What is the scientific reason behind it?

Answer

The wet cloth absorbs the heat from the body and decreases the temperature of the body through the process of evaporation. This is the reason why doctor’s advice to follow the above procedure.

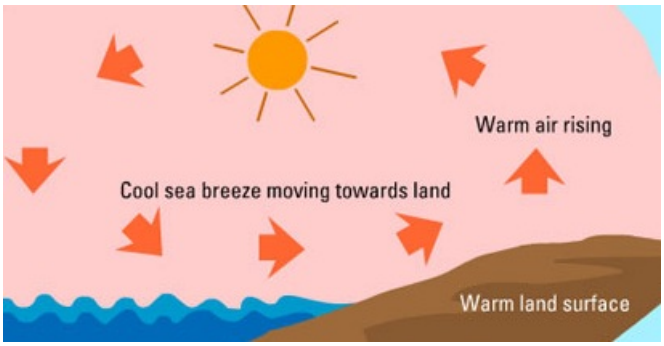
4. Question

“The high specific heat capacity of water causes land breeze and sea breeze”. Write down your comments

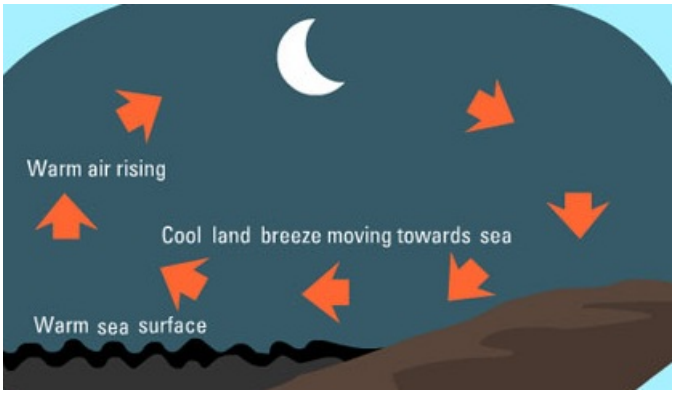
about this statement.

Answer

Sea breeze is the wind the blows from a large body water towards a land mass. During the day, Sun heats up land faster than water as water has high specific heat capacity than land. The warm air over land is less dense and begins to rise, this creates an area of low pressure. This causes air from above the sea to blow towards land, which is known as Sea Breeze.



In the night reverse process happens, since land cools faster than water due to high specific heat capacity of water, air above sea is warm and light and starts rising upwards. This creates a low-pressure area and air above the land starts flowing towards the sea. This is known as Sea Breeze.



5. Question

Write down an e× ample to know how the following factors influence the rate of evaporation.

(a) Surface area

(b) Wind

Answer

(a) If we take same quantity of water, one in a large surface are beaker and other in beaker having small surface area. We will keep both the beakers in sunlight, after few hours we will observe that quantity of water has decreased in the beaker having large surface area. Hence, increase in the surface, increases the rate of evaporation.

When we increase the surface area more no. of water molecule is e× posed to air, allowing water molecule to acquire more energy/heat from the surrounding. This energy helps molecule break hydrogen and other type of bond.

The progression is essentially more area → more heat absorption → increased kinetic energy → increased movement → faster Evaporation.

(b) On a windy day, the clothes dry faster than on a non-windy day. Hence, wind increases the rate of evaporation.

The wind sweeps away the airborne water particles that are in the air. The humidity of the air in the region is reduced, which allows more water molecules to dissipate in the air.

6. Question

When will cool drinks get cooled faster – on placing ice cubes at 0°C or on adding water at 0°C? Justify your answer.

Answer

Ice cubes at 0°C will cool faster than water at same temperature because ice has e× tra capacity to absorb heat in the form of latent heat of fusion i.e. energy required to convert water from solid state to liquid state at 273K.

7. Question

2 kg of water at 293 K is converted completely into ice at 273 K. Calculate the heat liberated.

Answer

Given:

Temperature = 293 K

Mass of water = 2kg

To convert water in liquid form to solid form.

Formula used:

$Q = mc(\Delta T)$

$Q = mF$

where m is the mass (Kg)

F is the latent heat of fusion of ice (J/kg)

c is the specific heat of water (J/kg-K)

ΔT is the temperature difference(K)

Step 1

Heat liberated in conversion from water at 293K to water 273K

ΔT = Initial temperature (of water) – Final temperature (of ice)

= 293K – 273K

= 20K

$Q = mc(\Delta T)$

$\Rightarrow Q_1 = 2 \text{ kg} \times 4.2 \times 10^3 \text{ J/kg-K} \times (20\text{K})$

$= 168 \times 10^3 \text{ J}$

STEP 2

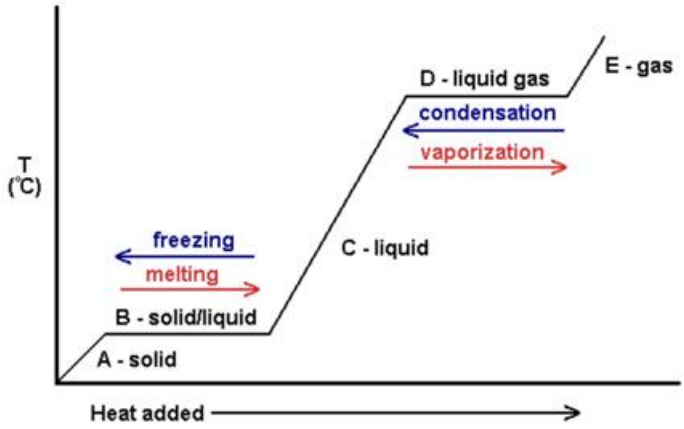
Heat liberated in conversion of water from liquid state to solid state.

$Q = mF$

$\Rightarrow Q_2 = 2 \text{ Kg} \times 336 \times 10^3 \text{ J/kg}$

$= 672 \times 10^3 \text{ J}$

The water diagram is shown here:



Total heat released = Sum of $Q_1 + Q_2 = 810 \times 10^3$ J

Ans = 810×10^3 J

Extended Activities

1. Question

2 kg of ice at –10°C is continuously heated to melt it completely. Calculate the quantity of heat required. (The latent heat of fusion of ice: 336×10^3 J/kg. The latent heat of vaporization of water: 226×10^4 J/kg. Specific heat capacity if ice: 2.1×10^3 J/kg K. Specific heat capacity of water: 4.2×10^3 J/kg K.)

Answer

Given

Mass of Ice at -10°C = 2Kg

To Find – Quantity of heat required to completely melt the ice.

Formula

$Q = mc(\Delta T)$

$Q = mF$

where m is the mass (Kg)

F is the latent heat of fusion of ice (J/kg)

c is the specific heat of ice (J/kg-K)

ΔT is the temperature difference(K)

Step 1

Heat required to change temperature of ice from -10°C to 0°C.

ΔT = Initial temperature – Final temperature

= 263K – 273K

= -10K

$Q = mc(\Delta T)$

m = 2kg

$c = 2.1 \times 10^3$ J/kg K

ΔT = -10K

$Q_1 = 2Kg \times 2.1 \times 10^3$ J/kg K × (-10K)

$Q_1 = -42 \times 10^3$ J (Negative sign shows that the heat is absorbed)

Step 2

Heat required to convert ice to water at 273K.

Q = mF

m = 2kg

$F = 336 \times 10^3$ J/kg

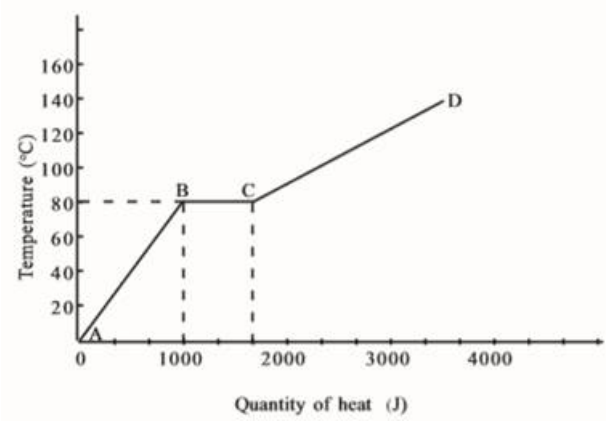
$Q_2 = 2kg \times 336 \times 10^3$ J/kg

$Q_2 = 672 \times 10^3$ J

Total heat required is $Q_1 + Q_2 = 714 \times 10^3$ J

2. Question

A solid of initial temperature 0°C is heated. A graph showing changes in the temperature according to the heat supplied is given below.



Based on the graph calculate the following. (Specific heat capacity of the substance: 500J kg^{-1} K^{-1})

(a) the mass of solid substance

(b) the latent heat of fusion of the substance

Answer

(a) The mass of the solid substance

Given

Specific heat capacity of the substance = 500J kg^{-1} K^{-1}

Energy to change temperature from 0C to 80C = 1000J

(from Graph)

Mass = ?

Formula used

Q = mc(ΔT)

m is the mass (Kg)

c is the specific heat of ice (J/kg-K)

ΔT is the temperature difference(K)

ΔT = 80

C = 500

Q = 1000

M = ?

500 J/kg-K × 80K × m(kg) = 1000J

M = 25gm

(b) the latent heat of fusion of the substance

Given

Mass of ice = 25gm

Energy from B to C = 1000J (to convert ice to water)

Latent heat of fusion = ?

Formula Used

Q = mF

where m is the mass (Kg)

F is the latent heat of fusion of ice (J/kg)

Q = 1000J

M = 25gm = 0.025 kg

F = ?

F J/Kg × 25/1000Kg = 1000J;

latent heat of fusion is 40000J/Kg.

3. Question

A hole was drilled in an ice block at 273 K. When the hole was filled with water at 373 K, 2 kg of ice melted and changed into water at 273 K. If so, what is the mass of water at 373 K that was used? (Specific heat capacity of water 4200 J kg^{-1} K^{-1}, latent heat of fusion of ice: 336 × 10^3 J/kg)

Answer

Given

Mass of water at 373K added = ?

Mass of ice melted and converted into water = 2Kg

Formula

Q = mc(ΔT)

Q = mF

where m is the mass (Kg)

F is the latent heat of fusion of ice (J/kg)

c is the specific heat of ice (J/kg-K)

ΔT is the temperature difference(K)

Step 1

Energy absorbed in conversion of ice to water at 273K

Q = mF

F = 336 × 10^3 J/kg

M = 2Kg

$Q = 672 \times 10^3$ J

Step 2

Energy released in changing the temperature of ‘m’ kg water from 373K to 273K .

$Q = mc\ (\Delta T)$

M = ?

$C = 4200\ J\ kg^{-1}\ K^{-1}$

$\Delta T = 100K$

$Q = m(kg) \times 100K \times 4200\ J\ kg^{-1}\ K^{-1}$

Since no e× ternal heat/ energy is provided , the heat absorbed in Step 1 is equal to heat released in Step 2.

Equating

$m(kg) \times 100K \times 4200\ J\ kg^{-1}\ K^{-1} = = 672 \times 10^3$ J

We get m = 1.6Kg

Mass of water added equal to 1.6 Kg.

4. Question

Collect information regarding different kinds of thermometers and record the situations in which they are used. (hint: ma× imum – minimum thermometer).

Answer

•Probe Thermometers - They deliver instant temperature readings of foods, liquids, and semi-solid samples. The probe is often equipped with a pointed tip making them ideal for penetration and immersion. They are ideal for use in the catering trade for hygiene testing, retail outlets, and laboratories.

•Infrared Thermometers - Infrared thermometers are one of the go-to types of thermometer for non-contact measurement. The non-contact feature makes them the best tool for measuring e× tremely high or low surface temperatures. It is common for them to include a laser targeting system designed to show the center of the measurement area.

•K – Type Thermometers - -Type thermocouples are one of the more specialized and niche types of thermometer. They deal with e× treme temperatures and are most common in laboratories and industry. This type of device caters for applications that need high precision.