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Solution for review question from chapter 4

1. Clearly distinguish among temperature, heat, and internal energy

Ans: *Temperature is a measure of molecular motion.*

Heat is energy in the process of being transferred between objects by random molecular collisions.

Internal energy is an object's energy of random molecular motion and molecular interaction.

2. What is wrong with the following statement? "Given any two objects, the one with the higher temperature contains more heat.

Ans: *Heat is a method of transferring energy, not energy contained in an object. Further, a low-temperature object with large mass, or an object made of a material with high specific heat, can contain more internal energy than a higher-temperature object*

3. The temperature of a silver bar rises by 10°C when it absorbs 1.23kJ of energy by heat. The mass of the bar is 525g. Determine the specific heat of silver.

Soln

$Q = mC_{silver}\Delta \mathrm{T}$

$C_{silver} = Q/m\Delta \mathrm{T}$

$C_{silver} = (0.525kg)(10.0C)1.23 \times 10_3 = 234J/kg.C$

4. Calculate the quantity of heat required to raise the temperature of 1 g of ice from $-10C$ to $110\ C$.

Soln

$$Q = m_i c_i \Delta T + m_i L_f + m_w c_w \Delta T + m_w L_v + m_s c_s \Delta T.$$

- *The amount of heat needed to raise the temperature of ice from -10^{0}c to 0^{0}c is* $m_i c_i \Delta T$ *and calculated as below.*

$$m_i c_i \Delta T = 1x10^{-3} kg x 2.1x10^3 J/kgc \; x \; 10C \; = \; 21J$$

- ***The amount of heat absorbed to change ice phase to water at to 0^0c is calculated with formula*** $m_i L_f$

$$m_i L_f = \; 1x10^{-3} kg \; x \; 3.34 \; \text{x} \frac{10^5 \; J}{kg} = 334J$$

- ***The amount of heat needed to raise the temperature of water from 0^0c to 100^0c is*** $m_w c_w \Delta T$

$$m_w c_w \Delta T = \; 1x10^{-3} \; cx \; 100℃ = \; 420J$$

- ***The amount of heat absorbed to change water to steam at 100^0c is calculated with formula*** $m_w L_v$

$$m_w L_v = \; 1x10^{-3} \; kgx \; 2.264 \; \text{x} \frac{10^6 \; J}{kg} = 2264J$$

- ***The amount of heat needed to raise the temperature of steam of water from 100^0c to 110^0c is*** $m_s c_s \Delta T$

$$m_s c_s \Delta T = \; 1x10^{-3} \; kgx \; 1.996 \; x10^3 \frac{J}{kgc} \; x \; 10^0 c = 19.96J$$

❖ ***Now the total heat required is***

$$Q = m_i c_i \Delta T + m_i L_f + m_w c_w \Delta T + m_w L_v + m_s c_s \Delta T =$$

$$Q = 21 \; J + 334 \; J + 418 \; J + 2264 \; J + 19.96 \; J = 3056.96 \; J.$$

5. If 20 g steam initially at $100C$ is added to 60 g of ice initially at $0C$, then find the final equilibrium temperature of the mixture.

Soln

- ***The heat energy lost by the steam is equal to the heat energy gained by the ice. The heat energy required to change the phase of ice at constant temperature 0 °C is Q_1 and the heat energy required to raise the temperature of water from 0 °C to final temperature T_f is Q_2.***

$$Q1 = m_{ice} L_f = 60 \; x \; 10^{-3} kg \; x \; 3.34 \; \text{x} \frac{10^5 \; J}{kg} = 20{,}040J$$

$$Q_2 = m_{ice}c_w(Tf - 0°C) = 60\ x\ 10^{-3}\ kg\ x\ 4.2\ x\frac{10^3 J}{ckg}\ Tf = 252Tf\ J/c$$

- ***The heat energy required to change the phase of steam at constant temperature 100 °C is*** $Q3$ ***and the heat energy required to lower the temperature of water from 100 °C to final temperature*** Tf ***is*** $Q4$.

$$Q3 = m_s Lv = 20\ x\ 10^{-3}\ kg\ x\ 2.264\ x\frac{10^6\ J}{kg} = 45.28x10^3 J$$

$$Q_4 = m_s c_w(100°C - Tf) = 20\ x\ 10^{-3}\ kg\ x\ x\ 4.2\ x\frac{10^3 J}{ckg}\ (100°C - Tf)$$

$$Q4 = 48J/c(100°C - Tf)$$

- ***Note: the heat energy lost by the steam is equal to the heat energy gained by the ice.***
- ***Hence***; $Q_1 + Q_2 = Q_3 + Q_4$

  - $20{,}040J + 252Tf\frac{J}{c} = 45.28x10^3\ J + 48J/c(100°C - Tf$
  - $252Tf\frac{J}{c} + 48\frac{J}{c} = 45{,}280J + 4800J - 20{,}040J$
  - $300Tf\ J/c = 30040J$
  - $Tf = 30040J/300\ J/c$
  - $Tf = 100.13°C$

6. A $50.0 - g$ sample of copper is at $25.0°C$. If $1200\ J$ of energy is added to it by heat, what is the final temperature of the copper?

Soln:

- ***Heat added to the sample as energy is given by*** $Q = mc\Delta T$, ***where m is the mass of sample of copper ,*** c ***is the specific heat of copper and*** ΔT ***is temperature difference produced due to absorbed energy.***

  - $Q = mc\Delta T$

- $\Delta T = {}^{Q}/_{mc} = \frac{\frac{1200J}{kg}}{50\,x10^{-3}\,x\,387\frac{J}{kgc}} = 62^0C$
- $\Delta T = Tf - Ti$
- $Tf = \Delta T + Ti$
- $Tf = 62^0C + 25^0C = 87^0C$

7. A system absorbs 35J of heat and in the process it does 11J of work.

(a) If the initial internal energy is 205J what is the final internal energy?

(b) The system follows a different thermodynamic path to the same final state and does 15J of work, what is the heat transferred?

Ans

a)

- ***From first law of thermodynamics, the change in internal energy is the summation of heat absorbed by the system and work done on the system.***
- $\Delta U = Q - W$
- $\Delta U = 35J - 11J = 24J$
  - ***The final internal energy is the summation of initial internal energy and increase in internal energy due to process and heat absorbed.***
- $Uf = Ui + \Delta U$
- $Uf = 205J + 24J = 229J$

b) ***When the system has the same final state with the problem in a), the its final internal energy is*** $Uf = 229J$.

- $\Delta U = Q - W$
- $\Delta U + W = Q$
- $Q = 24J + 15J$
- $Q = 39J$

8. A gas is compressed at a constant pressure of $0.800atm$ from 9.00 L to 2.00 L. In the process, 400 J of energy leaves the gas by heat.

a. What is the work done on the gas?

Answer :- The work done on the gas is calculated by using the equation,

- $W = -P\Delta V$
- $W = -P(Vf - Vi)$
- $W = 0.8\ x\ 1.013\ x10^5\ pa\ (9\ x\ 10^{-3}m^3 - 2\ x\ 10^{-3}m^3)$
- $W = 5.67x10^2\ J$

b. What is the change in its internal energy?

Answer:- For the change in the internal energy of the system, note that the sign convention for the heat is that it is negative when heat is released by the system and for work is positive when work is done on the system.

- $\Delta U = -Q + W$
- $\Delta U = -400J + 567J = 167J$

9. A gas is confined to a vertical cylinder by a piston of mass 2 kg and radius 1 cm. When 5J of heat are added, the piston rises by 2.4 cm. Atmospheric pressure is $10^5 Pa$. Find: a) the work done by the gas, the change in its internal energy. b) the change in its internal energy.

a)

Answer

- ***The work done is*** $W = -P\Delta V$
- $\Delta V = V_f - V_i$
- ***But the final volume of cylinder is*** $V_f = \pi r^2 h$ ***and the initial*** $V_i = 0$ ***by taking the*** $h_0 = 0$
- $V_f = 3.14\ x\ (1x10^{-2}m)^2\ x\ 2.4\ x10^{-2}m$
- $V_f = 7.54\ x10^{-6}m^3$
- ***Now the work done is*** $W = -10^5 Pa\ x\ 7.54\ x10^{-6}m^3 = -0.754J$

b)

Answer

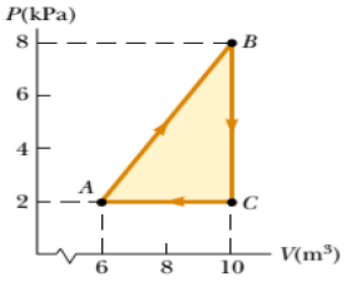
- ***The change in internal energy is the summation of both heat absorbed and work done***
- $\Delta U = Q - W = 5J - 0.754J = 4.246J$

10. A thermodynamic system undergoes a process in which its internal energy decreases by 500 J. At the same time, 220 J of work is done on the system. Find the energy transferred to or from it by heat.

Soln:

- ***From first law of thermodynamics*** $\Delta U = Q + W$ ***when is change in internal energy is the amount of heat absorbed and W is work done on the system.***
- $Q = -\Delta U + W = -500J + 220J = -180J$ ***It is heat transferred from the system to thesorround.***

11. A gas is taken through the cyclic process described in Figure.
a. Find the net energy transferred to the system by heat during one complete cycle.
b. If the cycle is reversed-that is, the process follows the path ACBA-what is the net energy input per cycle by heat?



a)

solution

- $W_{ABC} = w_{AB} + w_{BC} + w_{CA}$

- $W_{ABC} = Area\ of\ triangle$
- $W_{ABC} = {}^{1}/_{2}\,(8-2)kPa\ x(10-6)m^3$
- $W_{ABC} = 3Pa\ x\ 4m^3$
- $W_{ABC} = 12kJ$ ***This is the net energy transferred to the system by heat during one complete cycle.***

b)

- ***If the cycle is reversed-that is, the process follows the path ACBA- and the net energy input per cycle by heat is negative of the energy input in forward process.***

- $W_{ACB} = -W_{ABC} = -12kJ$