# THERMODYNAMICS

## FACT/DEFINITION TYPE QUESTIONS

1. The branch of physics that deals with the concepts of heat and temperature and the interconversion of heat and other forms of energy is called
   (a) calorimetry (b) thermometry
   (c) thermodynamics (d) Pyrometry
2. Thermodynamics is concerned in part with transformations between
   (a) different forms of heat energy
   (b) internal energy at various temperatures
   (c) one form of mechanical energy into other forms
   (d) heat, internal energy and mechnical work
3. A system $X$ is neither in thermal equilibrium with $Y$ nor with $Z$. The systems $Y$ and $Z$
   (a) must be in thermal equilibrium
   (b) cannot be in thermal equilibrium
   (c) may be in thermal equilibrium
   (d) None of these
4. When two bodies A and B are in thermal equilibrium
   (a) the kinetic energies of all the molecules of A and B will be equal
   (b) the potential energies of all the molecules of A and B will be equal
   (c) the internal energies of the two bodies will be equal
   (d) the average kinetic energy of the molecules of the two bodies will be equal
5. Temperature is a measurement of coldness or hotness of an object. This definition is based on
   (a) Zeroth law of thermodynamics
   (b) First law of thermodynamics
   (c) Second law of thermodynamics
   (d) Newton's law of cooling
6. The first law of thermodynamics expresses
   (a) law of conservation of momentum
   (b) law of conservation of energy
   (c) law of conservation of mass
   (d) All of the above
7. The first law of thermodynamics is a special case of
   (a) Newton's law
   (b) the law of conservation of energy
   (c) Charle's law
   (d) the law of heat exchange
8. Energy transfer brought about by moving the piston of a cylinder containing the gas is known as
   (a) work (b) heat
   (c) pressure (d) temperature
9. Which of the following macroscopic variable is not measurable ?
   (a) Pressure (b) Volume
   (c) Mass (d) None of these
10. Which of the following is a state variable ?
    (a) Heat (b) Work
    (c) Internal energy (d) All of these
11. The internal energy of an ideal gas is a function of
    (a) pressure (b) volume
    (c) temperature (d) All of the above
12. The internal energy of an ideal gas depends upon
    (a) specific volume (b) pressure
    (c) temperature (d) density
13. At a given temperature the internal energy of a substance
    (a) in liquid state is equal to that in gaseous state.
    (b) in liquid state is less than that in gaseous state.
    (c) in liquid state is more than that in gaseous state.
    (d) is equal for the three states of matter.
14. The variable defined by Zeroth law of thermodynamics is
    (a) temperature (b) internal energy
    (c) work (d) All of these
15. The internal energy of an ideal gas does not depend upon
    (a) temperature of the gas
    (b) pressure of the gas
    (c) atomicity of the gas
    (d) number of moles of the gas.

16. If $\Delta Q$ and $\Delta W$ represent the heat supplied to the system and the work done on the system respectively, then the first law of thermodynamics can be written as

(a) $\Delta Q = \Delta U + \Delta W$ (b) $\Delta Q = \Delta U - \Delta W$

(c) $\Delta Q = \Delta W - \Delta U$ (d) $\Delta Q = -\Delta W - \Delta U$

17. Which of the following is incorrect regarding first law of thermodynamics?

(a) It is a restatement of principle of conservation of energy.

(b) It is applicable to cyclic processes

(c) It introduces the concept of entropy

(d) It introduces the concept of internal energy

18. First law of thermodynamics states that

(a) system can do work

(b) system has temperature

(c) system has pressure

(d) heat is a form of energy

19. Which of the following statements is correct for any thermodynamic system ?

(a) The change in entropy can never be zero

(b) Internal energy and entropy are state functions

(c) The internal energy changes in all processes

(d) The work done in an adiabatic process is always zero.

20. For one mole of solid, at constant pressure how is $C$ related to $R$ ? ($C \rightarrow$ moler specific heat, $R \rightarrow$ universal gas constant)

(a) $C = \dfrac{3R}{T}$ (b) $C = 3R$

(c) $C = \dfrac{1}{3}RT$ (d) $C = \dfrac{1}{3}R$

21. If $C_P$ and $C_V$ are specific heat capacities at constant pressure and constant volume respectively, then for an adiabatic process of an ideal gas

(a) $PV$ = constant (b) $PV^{-\gamma}$ = constant

(c) $PV^{\gamma}$ = constant (d) $\dfrac{P}{V^{\gamma}}$ = constant

22. For an ideal gas, the molar specific heat capacities at constant pressure and volume satisfy the relation

(a) $C_P + C_V = R$ (b) $C_P - C_V = R$

(c) $\dfrac{C_P}{C_V} = R$ (d) $\dfrac{C_V}{C_P} = R$

23. Which of the following formula is wrong?

(a) $C_V = \dfrac{R}{\gamma - 1}$ (b) $C_P = \dfrac{\gamma R}{\gamma - 1}$

(c) $C_P / C_V = \gamma$ (d) $C_P - C_V = 2R$

24. $\gamma$ for a gas is always

(a) negative (b) zero

(c) between zero and one (d) more than one

25. The specific heat of a gas at constant pressure is greater than the specific heat of the same gas at constant volume because

(a) work is done in the expansion of the gas at constant pressure.

(b) work is done in the expansion of the gas at constant volume.

(c) the attraction between the molecules increases at constant pressure.

(d) the molecular attraction increases at constant volume.

26. Which of the following holds good for an isochoric process?

(a) No work is done on the gas

(b) No work is done by the gas

(c) Both (a) and (b)

(d) None of these

27. Which process will increase the temperature of the system without heating it ?

(a) Adiabatic compression

(b) Adiabatic expansion

(c) Isothernal compression

(d) Isothernal expansion

28. The state of a thermodynamic system is represented by

(a) Pressure only

(b) Volume only

(c) Pressure, volume and temperature

(d) Number of moles

29. Which of the following is not a thermodynamics co-ordinate?

(a) P (b) T

(c) V (d) R

30. The specific heat of a gas in an isothermal process is

(a) infinite (b) zero

(c) negative (d) remains constant

31. The work done in an adiabatic change in a particular gas depends only upon

(a) change in volume

(b) change in temperature

(c) change in pressure

(d) None of these

32. Which one of the following is an isoentropic process?

(a) Isothermal (b) Adiabatic

(c) Isochoric (d) Isobaric

33. In all natural processes, the entropy of the universe
(a) remains constant
(b) always decreases
(c) always increases
(d) may increase or decrease

34. During isothermal expansion, the slope of $P$-$V$ graph
(a) decreases (b) increases
(c) remains same (d) may increase or decrease

35. Which of the following processes is adiabatic ?
(a) Melting of ice
(b) Bursting of tyre
(c) Motion of piston of an engine with constant speed
(d) None of these

36. For adiabatic processes (Letters have usual meanings)
(a) $P^{\gamma}V$ = constant (b) $T^{\gamma}V$ = constant
(c) $TV^{\gamma-1}$ = constant (d) $TV^{\gamma}$ = constant

37. We consider a thermodynamic system. If $\Delta U$ represents the increase in its internal energy and W the work done by the system, which of the following statements is true?
(a) $\Delta U = -W$ in an adiabatic process
(b) $\Delta U = W$ in an isothermal process
(c) $\Delta U = -W$ in an isothermal process
(d) $\Delta U = W$ in an adiabatic process

38. Ice contained in a beaker starts melting when
(a) the specific heat of the system is zero
(b) internal energy of the system remains constant
(c) temperature remains constant
(d) entropy remains constant

39. Which of the following parameters does not characterize the thermodynamic state of matter?
(a) Temperature (b) Pressure
(c) Work (d) Volume

40. A point on P – V diagram represents
(a) the condition of a system
(b) work done on or by the system
(c) work done in a cyclic process
(d) a thermodynamic process

41. The slopes of isothermal and adiabatic curves are related as
(a) isothermal curve slope = adiabatic curve slope
(b) isothermal curve slope = $\gamma \times$ adiabatic curve slope
(c) adiabatic curve slope = $\gamma \times$ isothermal curve slope
(d) adiabatic curve slope = $\frac{1}{2} \times$ isothermal curve slope

42. A sample of gas expands from volume $V_1$ to $V_2$. The amount of work done by the gas is greatest when the expansion is
(a) isothermal (b) isobaric
(c) adiabatic (d) equal in all cases

43. Choose the incorrect statement related to an isobaric process.
(a) $\frac{V}{T}$ = constant
(b) $W = P\Delta V$
(c) Heat given to a system is used up in raising the temperature only.
(d) $\Delta Q > W$

44. In thermodynamic processes which of the following statements is not true?
(a) In an isochoric process pressure remains constant
(b) In an isothermal process the temperature remains constant
(c) In an adiabatic process $PV^{\gamma}$ = constant
(d) In an adiabatic process the system is insulated from the surroundings

45. When heat is given to a gas in an isothermal change, the result will be
(a) external work done
(b) rise in temperature
(c) increase in internal energy
(d) external work done and also rise in temperature

46. Which of the following statements about a thermodynamic process is wrong ?
(a) For an adiabatic process $\Delta E_{int} = -W$
(b) For a constant volume process $\Delta E_{int} = +Q$
(c) For a cyclic process $\Delta E_{int} = 0$
(d) For free expansion of a gas $\Delta E_{int} > 0$

47. No heat flows between the system and surrounding. Then the thermodynamic process is
(a) isothermal (b) isochoric
(c) adiabatic (d) isobaric

48. The coefficient of performance of a refrigerator is given by
(a) $\frac{\theta_2}{\theta_1 - \theta_2}$ (b) $\frac{\theta_1}{\theta_1 - \theta_2}$
(c) $\frac{\theta_1 - \theta_2}{\theta_2}$ (d) $\frac{\theta_1 - \theta_2}{\theta_1}$

49. A refrigerator is a
(a) heat engine
(b) an electric motor
(c) heat engine working in backward direction
(d) air cooler

50. Air conditioner is based on the principle of
(a) Carnot cycle
(b) refrigerator
(c) first law of thermodynamics
(d) None of these

51. "Heat cannot by itself flow from a body at lower temperature to a body at higher temperature" is a statement or consequence of
(a) second law of thermodynamics
(b) conservation of momentum
(c) conservation of mass
(d) first law of thermodynamics

52. The second law of thermodynamics implies
(a) whole of the heat can be converted into mechanical energy
(b) no heat engine can be 100% efficient
(c) every heat engine has an efficiency of 100%
(d) a refrigerator can reduce the temperature to absolute zero

53. In a cyclic process, work done by the system is
(a) zero
(b) equal to heat given to the system
(c) more than heat given to the system
(d) independent of heat given to the system

54. Which of the following processes is reversible?
(a) Transfer of heat by conduction
(b) Transfer of heat by radiation
(c) Isothermal compression
(d) Electrical heating of a nichrome wire

55. Which of the following processes is irreversible?
(a) Transfer of heat by radiation
(b) Adiabatic changes performed slowly
(c) Extremely slow extension of a spring
(d) Isothermal changes performed slowly

56. In a reversible cyclic process of a gaseous system
(a) $\Delta Q = \Delta U$ (b) $\Delta U = \Delta W$
(c) $\Delta W = 0$ (d) $\Delta U = 0$

57. Choose the correct relation between efficiency $\eta$ of a Carnot engine and the heat absorbed $(\theta_1)$ and released by the working substance $(\theta_2)$.
(a) $\eta = 1+\frac{\theta_2}{\theta_1}$ (b) $\eta = 1+\frac{\theta_1}{\theta_2}$
(c) $\eta = 1-\frac{\theta_1}{\theta_2}$ (d) $\eta = 1-\frac{\theta_2}{\theta_1}$

58. Universal relation in a Carnot cycle is
(a) $\frac{\theta_1}{\theta_2} = \frac{T_2}{T_1}$ (b) $\frac{\theta_1}{\theta_2} = \frac{T_1}{T_2}$
(c) $\frac{\theta_1}{\theta_2} = \frac{P_1}{P_2}$ (d) All of these

59. The correct relation between coefficient of performance and efficiency of refrigerator is
(a) $\beta = \frac{1+\eta}{\eta}$ (b) $\beta = \frac{1-\eta}{\eta}$
(c) $\beta = 1 + \eta$ (d) None of these

60. A Carnot engine works between a source and a sink maintained at constant temperatures $T_1$ and $T_2$. For efficiency to be the greatest
(a) $T_1$ and $T_2$ should be high
(b) $T_1$ and $T_2$ should be low
(c) $T_1$ should be low and $T_2$ should be high
(d) $T_1$ should be high and $T_2$ should be low

61. Efficiency of carnot engine is 100% if
(a) $T_2 = 273$ k (b) $T_2 = 0$ k
(c) $T_1 = 273$ k (d) $T_1 = 0$ k

62. The first operation involved in a Carnot cycle is
(a) isothermal expansion
(b) adiabatic expansion
(c) isothermal compression
(d) adiabatic compression

63. Which of the following statements is incorrect?
(a) All reversible cycles have same efficiency
(b) Reversible cycle has more efficiency than an irreversible one
(c) Carnot cycle is a reversible one
(d) Carnot cycle has the maximum efficiency in all cycles

64. Even Carnot engine cannot give 100% efficiency because we cannot
(a) prevent radiation
(b) find ideal sources
(c) reach absolute zero temperature
(d) eliminate friction

65. Heat engine is a device by which a system is made to undergo a ...*X*... process that result in conversion of ...*Y*... into work.
Here, *X* and *Y* refer to
(a) isothermal and heat (b) cyclic and heat
(c) cyclic and work (d) adiabatic and heat

66. A thermodynamic process is reversible if the process can be turned back such that both the system and the surrounding return to their ...X... with no other ...Y... any where in the universe. Here, *X* and *Y* respectively refer to
(a) normal states and change
(b) original states and change
(c) final states and change
(d) None of these

67. An ideal gas is compressed to half its initial volume by means of several processes. Which of the process results in the maximum work done on the gas?
(a) Isobaric (b) Isochoric
(c) Isothermal (d) Adiabatic

68. A measure of the degree of disorder of a system of a system is known as
(a) enthalpy (b) isotropy
(c) entropy (d) None of these

## STATEMENT TYPE QUESTIONS

69. Which of the following statements are incorrect ?
I. If $Q > 0$, heat is added to the system.
II. If $W > 0$, work is done by the system.
III. If $W = 0$, work is done by the system.
(a) II and III (b) I, II and III
(c) I and II (d) I and III

70. Choose the false statement(s) from the following.
I. Specific heat of a substance depends on the mass of substance.
II. Specific heat of substance depends on the temperature of the substance.
III. Specific heat depends on the nature of material.
(a) I only (b) II only
(c) I and II (d) I, II and III

71. Which of the following statements is/are true about internal energy ?
I. Internal energy of a gas does not change in an isothermal process.
II. Internal energy of a gas does not change in an adiabatic process
III. Internal energy of a gas change in an isothermal process
(a) I only (b) II only
(c) III only (d) II and III

72. Select the false statement(s) from the following.
I. Two isothermal curves can never intersect each other.
II. When air rises up it cools.
III. A gas gets cooled on compression.
(a) I only (b) II only
(c) III only (d) I and II

73. Which of the following statements are correct about isothermal and adiabatic changes ?
I. Isothermal system is thermally conducting to the surroundings.
II. Adiabatic system is thermally insulated from the surroundings.
III. Internal energy changes in isothermal process.
(a) I and II (b) II and III
(c) I and II (d) I, II and III

74. Which of the following is/are the statements of Second law of thermodynamics ?
I. No process is possible whose sole result is the absorption of heat from a reservoir and complete conversion of heat into work.
II. No process is possible whose sole result is the transfer of heat from a colder object to a hotter object.
(a) I only (b) II only
(c) I and II (d) None of these

75. Consider the following statements and select the correct option.
I. A real engine has efficiency greater than that of Carnot engine.
II. A real engine can't have efficiency greater than that of Carnot engine.
III. Working substance in Carnot engine is an ideal gas.
(a) I only (b) II only
(c) I and II (d) I, II and III

76. Choose the correct statements from the following.
I. Efficeincy of Carnot engine cannot be 100%.
II. Two systems in thermal equilibrium with a third system are in equilburium with each other.
III. Change in internal energy in the melting process is due to change in internal potential energy.
(a) I and II (b) II and III
(c) I and III (d) I, II and III

77. Which of the following statements are incorrect ?
I. Carnot cycle consists of three isothermal process connected by one adiabatic process.
II. Carnot engine is a reversible engine.
III. Efficiency of Carnot engine is 100%.
(a) II and III (b) I, II and III
(c) I and II (d) I and III

78. Internal energy
I. is microscopic state variable.
II. is microscopic state variable.
III. depends on the state of the system, not how that state is achieved.
IV. is a thermodynamics state variable
Choose the correct option regarding above statements.
(a) I and III (b) II, III and IV
(c) I, III and IV (d) I and IV

79. Choose the correct statements from the following.
I. Free expansion of gas is an irreversible process.
II. The combustion reaction of a mixture of petrol and air ignited by a spark is irreversible.
III. The leaking of a gas from the kitchen cylinder cannot be reversed by itself.
IV. The transfer of heat from one heated part of a liquid to the other colder part is a irreversible process.
(a) I, II and IV
(b) III and IV
(c) II, III and IV
(d) I, II, III and IV

## MATCHING TYPE QUESTIONS

**80.** Match columns I and II.

| | **Column-I** | | **Column-II** |
|---|---|---|---|
| (A) | Isothermal | (1) | $\Delta Q = 0$ |
| (B) | Isobaric | (2) | Volume constant |
| (C) | Isochoric | (3) | Pressure constant |
| (D) | Adiabatic | (4) | Temperature constant |

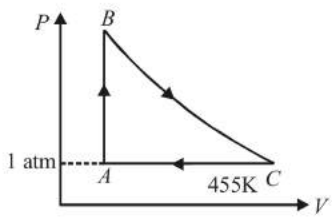
(a) (A) – (4), (B) – (3), (C) – (2), D – (1)
(b) (A) – (1), (B) – (4), (C) – (3), D – (2)
(c) (A) – (2), (B) – (3), (C) – (1), (D) – (4)
(d) (A) – (3), (B) – (1), (C) – (2), (D) – (4)

**81.**

| | **Column-I** | | **Column-II** |
|---|---|---|---|
| (A) | The coefficient of volume expansion at constant pressure | (1) | decrease in pressure |
| (B) | At constant temperature, an increase in volume results in | (2) | at all temperature |
| (C) | An ideal gas obeys Boyle's and Charle's law | (3) | same for all gases |
| (D) | A real gas behaves as an ideal gas at low pressure | (4) | at high temperature |

(a) (A) – (3), (B) – (1), (C) – (2), D – (4)
(b) (A) – (4), (B) – (3), (C) – (2), D – (1)
(c) (A) – (1), (B) – (2), (C) – (3), (D) – (4)
(d) (A) – (2), (B) – (4), (C) – (3), (D) – (1)

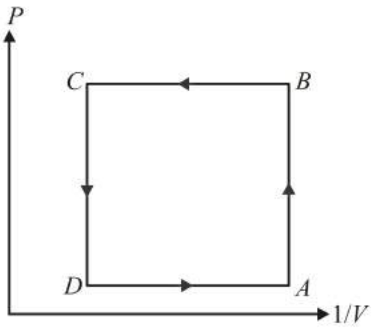
**82.** The P-V diagram of 0.2 mol of a diatomic ideal gas is shown in figure. Process BC is adiabatic, $\gamma = 1.4$.




| | **Column I** | | **Column II** |
|---|---|---|---|
| (A) | $\Delta Q_{AB}$ (J) | (1) | 602 |
| (B) | $\Delta W_{BC}$ (J) | (2) | –644 |
| (C) | $\Delta U_{CA}$ (J) | (3) | 1246 |
| (D) | $\Delta U_{BC}$ (J) | (4) | –602 |

(a) (A) – (1), (B) – (3), (C) – (4), D – (2)
(b) (A) – (3), (B) – (1), (C) – (2), D – (4)
(c) (A) – (3, 4), (B) – (3), (C) – (2), (D) – (1)
(d) (A) – (1), (B) – (2), (C) – (3), (D) – (4)

**83.** A gas undergoes a process according to the graph. $P$ is pressure, $V$ is volume, $W$ is work done by the gas, $\Delta U$ is change in internal energy of the gas and $\Delta Q$ is heat given to the system. Matchf the two columns.

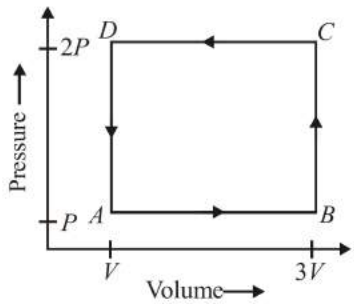



| | **Column-I** | | **Column -II** |
|---|---|---|---|
| (A) | For process $AB$ | (1) | $\Delta U > 0, \Delta Q > 0$ |
| (B) | For process $BC$ | (2) | $\Delta U < 0, \Delta Q < 0$ |
| (C) | For process $CD$ | (3) | $\Delta Q \times \Delta U \times W = 0$ |
| (D) | For process $DA$ | (4) | $\Delta Q \times \Delta U < 0$ |

(a) (A) – (1), (B) – (2), (C) – (4), D – (3)
(b) (A) – (3), (B) – (1), (C) – (2), D – (2)
(c) (A) – (2), (B) – (1), (C) – (4), (D) – (3)
(d) (A) – (4), (B) – (3), (C) – (2), (D) – (1)

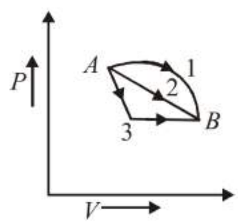
## DIAGRAM TYPE QUESTIONS

**84.** A thermodynamic system is taken through the cycle $ABCD$ as shown in figure. Heat rejected by the gas during the cycle is




(a) 2PV
(b) 4PV
(c) $\frac{1}{2}$ PV
(d) PV

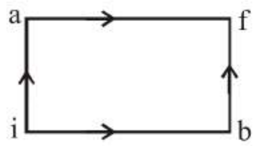
**85.** An ideal gas goes from state $A$ to state $B$ via three different processes as indicated in the $P$-$V$ diagram




If $Q_1, Q_2, Q_3$ indicate the heat absorbed by the gas along the three processes and $\Delta U_1, \Delta U_2, \Delta U_3$ indicate the change in internal energy along the three processes respectively, then

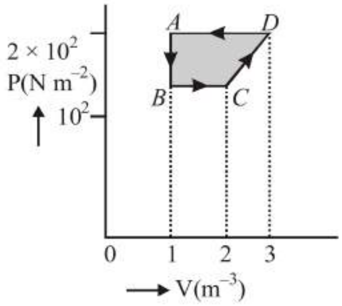
(a) $Q_1 > Q_2 > Q_3$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$
(b) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$
(c) $Q_1 = Q_2 = Q_3$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$
(d) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$

**86.** When a system is taken from state i to state f along the path iaf, it is found that Q = 50 cal and W = 20 cal. Along the path ibf Q = 36 cal. W along the path ibf is



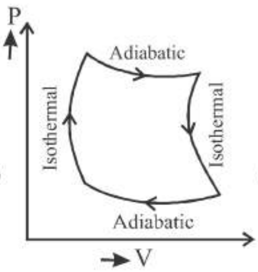

(a) 14 cal (b) 6 cal
(c) 16 cal (d) 66 cal

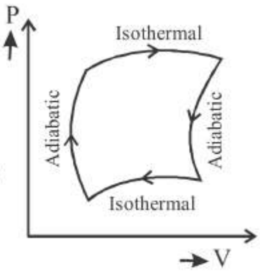
**87.** The *P-V* diagram of a gas system undergoing cyclic process is shown here. The work done during isobaric compression is

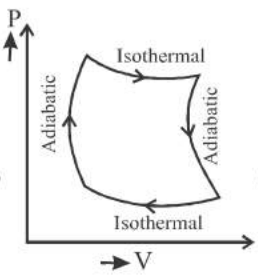


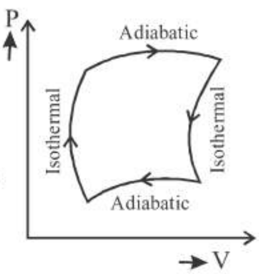

(a) 100 J (b) 200 J
(c) 600 J (d) 400 J

**88.** Which of the following is the *P-V* curve for isothermal and adiabatic process of an ideal gas ?

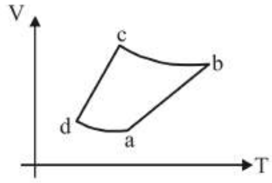
(a)



(b)


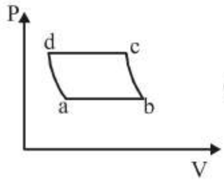

(c)


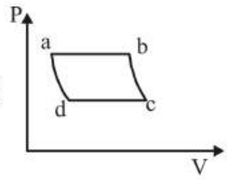

(d)


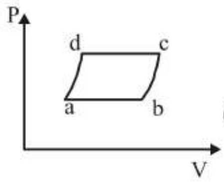

**89.** An ideal gas goes through a reversible cycle a→b→c→d has the V - T diagram shown below. Process d→a and b→c are adiabatic.

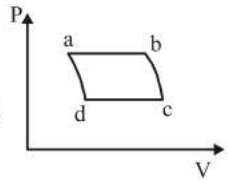



The corresponding P - V diagram for the process is

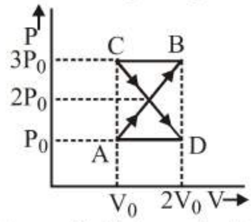
(a)



(b)



(c)


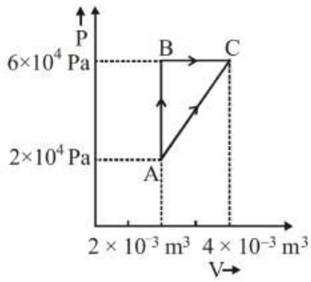

(d)



**90.** A thermodynamic system undergoes cyclic process ABCDA as shown in fig. The work done by the system in the cycle is




(a) $P_0V_0$
(b) $2P_0V_0$
(c) $\frac{P_0V_0}{2}$
(d) Zero

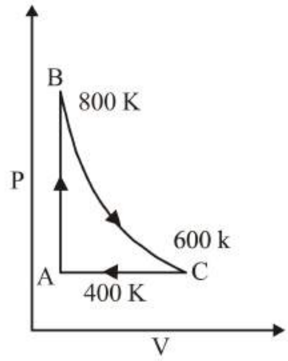
**91.** Figure below shows two paths that may be taken by a gas to go from a state A to a state C.




In process AB, 400 J of heat is added to the system and in process BC, 100 J of heat is added to the system. The heat absorbed by the system in the process AC will be

(a) 500 J (b) 460 J
(c) 300 J (d) 380 J

**92.** One mole of a diatomic ideal gas undergoes a cyclic process ABC as shown in figure. The process BC is adiabatic. The temperatures at A, B and C are 400 K, 800 K and 600 K respectively. Choose the correct statement:



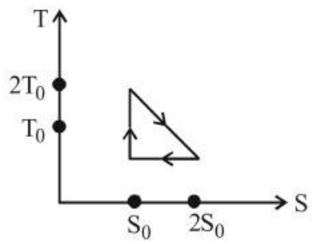

(a) The change in internal energy in whole cyclic process is 250 R.

(b) The change in internal energy in the process CA is 700 R.

(c) The change in internal energy in the process AB is -350 R.

(d) The change in internal energy in the process BC is – 500 R.

93. The temperature-entropy diagram of a reversible engine cycle is given in the figure. Its efficiency is




(a) $\frac{1}{4}$ (b) $\frac{1}{2}$

(c) $\frac{2}{3}$ (d) $\frac{1}{3}$

## ASSERTION- REASON TYPE QUESTIONS

**Directions** : Each of these questions contain two statements, Assertion and Reason. Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.

(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion

(c) Assertion is correct, reason is incorrect

(d) Assertion is incorrect, reason is correct.

94. **Assertion :** Zeroth law of thermodynamics explain the concept of energy.
**Reason :** Energy depends on temperature.

95. **Assertion:** Mass of a body will increase when it is heated.
**Reason:** The internal energy of a body increases on heating.

96. **Assertion:** Heat cannot be added to a system without increasing its temperature.
**Reason:** Adding heat will increase the temperature in every situation.

97. **Assertion :** The heat supplied to a system is always equal to the increase in its internal energy.
**Reason :** When a system changes from one thermal equilibrium to another, some heat is absorbed by it.

98. **Assertion :** In isothermal process whole of the heat energy supplied to the body is converted into internal energy.
**Reason :** According to the first law of thermodynamics $\Delta Q = \Delta U + W$.

99. **Assertion :** First law of thermodynamics is a restatement of the principle of conservation
**Reason :** Energy is fundamental quantity

100. **Assertion :** At a given temperature the specific heat of a gas at constant volume is always greater than its specific heat at constant pressure.
**Reason :** When a gas is heated at constant volume some extra heat is needed compared to that at constant pressure for doing work in expansion.

101. **Statement-1 :** The specific heat of a gas in an adiabatic process is zero but it is infinite in an isothermal process.
**Statement-2 :** Specific heat of a gas directly proportional to heat exchanged with the system and inversely proportional to change in temperature.

102. **Assertion :** Adiabatic expansion is always accompanied by fall in temperature.
**Reason :** In adiabatic process, volume is inversely proportional to temperature.

103. **Assertion :** When a bottle of cold carbonated drink is opened a slight fog forms around the opening.
**Reason :** Adiabatic expansion of the gas causes lowering of temperature and condensation of water vapours.

104. **Assertion :** In an adiabatic process, change in internal energy of a gas is equal to work done on or by the gas in the process.
**Reason :** Temperature of gas remains constant in an adiabatic process.

105. **Assertion :** The isothermal curves intersect each other at a certain point.
**Reason :** The isothermal change takes place slowly, so the isothermal curves have very little slope

106. **Assertion :** In an isolated system the entropy increases.
**Reason :** The processes in an isolated system are adiabatic.

107. **Assertion:** In an adiabatic process, change in internal energy of a gas is equal to work done on/by the gas.
**Reason:** Because adiabatic process is a variable process and so internal energy depends on the work done.

108. **Assertion:** Two isothermal curves can never intersect each other.

**Reason:** At the intersection point, at two different temperatures, volume and pressures of gas will be same which is not possible.

109. **Assertion :** The temperature of the surface of the sun is approximately 6000 K. If we take a bigh lens and focus the sunrays, we can produce a temperature of 8000 K.

**Reason :** The highest temperature can be produced according to second law of thermodynamics

110. **Assertion :** When a glass of hot milk is placed in a room and allowed to cool, its entropy decreases

**Reason :** Allowing hot object to cool does not violate the second law of thermodynamics.

111. **Assertion:** The efficiency of a reversible engine is maximum.

**Reason:** In such a device no dissipation of energy takes place.

112. **Assertion :** Reversible systems are difficult to find in real world.

**Reason :** Most processes are dissipative in nature.

113. **Assertion :** Thermodynamic processes in nature are irreversible

**Reason :** Dissipative effects can not be eliminated.

114. **Assertion :** In cyclic process, initial and final state are same. Therefore net work done is zero.

**Reason :** Initial and final temperature is equal, therefore change in internal energy is zero.

115. **Assertion :** Efficiency of a Carnot engine increase on reducing the temperature of sink.

**Reason :** Efficiency of a Carnot engine is defined as the ratio of net mechanical work done per cycle by the gas to the amount of heat energy absorbed per cycle from the source.

116. **Assertion :** The Carnot cycle is useful in understandsing the performance of heat engines.

**Reason :** The Carnot cycle provides a way of determining the maximum possible efficiency achievable with reservoirs of given temperatures.

## CRITICAL THINKING TYPE QUESTIONS

117. When the state of a gas adiabatically changed from an equilibrium state A to another equilibrium state B an amount of work done on the stystem is 35 J. If the gas is taken from state A to B via process in which the net heat absorbed by the system is 12 cal, then the net work done by the system is (1 cal = 4.19 J)

(a) 13.2 J (b) 15.4 J
(c) 12.6 J (d) 16.8 J

118. The internal energy change in a system that has absorbed 2 kcals of heat and done 500 J of work is

(a) 6400 J (b) 5400 J
(c) 7900 J (d) 8900 J

119. The specific heat at constant pressure of an ideal gas, $C_p = \frac{5R}{2}$. The gas is kept in a closed vessel of volume 0.0083 $m^3$ at 300 K and a pressure of $1.6 \times 10^6$ N/$m^2$. $2.49 \times 10^4$ J of heat energy is supplied to the gas. The final temperature and the pressure respectively are

(a) 567.2 K and $6.3 \times 10^6$ N/$m^2$
(b) 675.2 K and $3.6 \times 10^6$ N/$m^2$
(c) 275.2 K and $2.3 \times 10^6$ N/$m^2$
(d) 465.6 K and $4.2 \times 10^6$ N/$m^2$

120. The specific heat capacity of a metal at low temperature ($T$) is given as $C_p(\text{kJK}^{-1}\text{kg}^{-1}) = 32\left(\frac{T}{400}\right)^3$. A 100 g vessel of this metal is to be cooled from 20 K to 4 K by a special refrigerator operating at room temperature (27°C). The amount of work required to cool in vessel is

(a) equal to 0.002 kJ
(b) greater than 0.148 kJ
(c) between 0.148 kJ and 0.028 kJ
(d) less than 0.028 kJ

121. The amount of heat supplied to $4 \times 10^{-2}$ kg of nitorgen at room temperature to rise its temperature by 50°C at constant pressure is (Molecular mass of nitrogen is 28 and R = 8.3 J $mol^{-1}K^{-1}$)

(a) 2.08 kJ (b) 3.08 kJ
(c) 4.08 kJ (d) 5.08 kJ

122. When 1 kg of ice at 0°C melts to water at 0°C, the resulting change in its entropy, taking latent heat of ice to be 80 cal/°C, is

(a) 273 cal/K (b) 8 × 104 cal/K
(c) 80 cal/K (d) 293 cal/K

123. A mass of diatomic gas ($\gamma$ = 1.4) at a pressure of 2 atmospheres is compressed adiabatically so that its temperature rises from 27°C to 927°C. The pressure of the gas in final state is

(a) 28 atm (b) 68.7 atm
(c) 256 atm (d) 8 atm

124. A diatomic gas initially at 18ºC is compressed adiabatically to one eighth of its original volume. The temperature after compression will be

(a) 18ºC (b) 668.4ºK
(c) 395.4ºC (d) 144ºC

125. 2 k mol of hydrogen at NTP expands isobarically to twice its initial volume. The change in its internal energy is ($C_v$ = 10 kJ/kg.K and atm pressure = $1 \times 10^5$ N/$m^2$)

(a) 10.9 MJ (b) 9.10 MJ
(c) 109 MJ (d) 1.09 MJ

**126.** What will be the final pressure if an ideal gas in a cylinder is compressed adiabatically to $\frac{1}{3}$rd of its volume?

(a) Final pressure will be three times less than initial pressure.
(b) Final pressure will be three times more than initial pressure.
(c) Change in pressure will be more than three times the initial pressure.
(d) Change in pressure will be less than three times the initial pressure.

**127.** In a heat engine, the temperature of the source and sink are 500 K and 375 K. If the engine consumes $25 \times 10^5$ J per cycle, the work done per cycle is

(a) $6.25 \times 10^5$ J (b) $3 \times 10^5$ J
(c) $2.19 \times 10^5$J (d) $4 \times 10^4$ J

**128.** A refrigerator with coefficient of performance $\frac{1}{3}$ releases 200 J of heat to a hot reservoir. Then the work done on the working substance is

(a) $\frac{100}{3}$J (b) 100 J
(c) $\frac{200}{3}$J (d) 150 J

**129.** If the co-efficient of performance of a refrigerator is 5 and operates at the room temperature 27°C, the temperature inside the refrigerator is

(a) 240 K (b) 250 K
(c) 230 K (d) 260 K

**130.** By running a refrigerator with open door in a room

(a) the temperature of the room will reduce a little
(b) the room can be cooled considerably but this will take a long time
(c) the room will get a little hotter
(d) None of these

**131.** If an air conditioner is put in the middle of a room and started working

(a) the room can be cooled slightly
(b) the temperature of the room will not change
(c) the room will become slightly warmer
(d) the same temperature will be attained in the room as by putting it on the window in the standard position

**132.** A monoatomic gas at a pressure P, having a volume V expands isothermally to a volume 2V and then adiabatically to a volume 16V. The final pressure of the gas is : (take $\gamma = \frac{5}{3}$)

(a) 64P (b) 32P
(c) $\frac{P}{64}$ (d) 16P

**133.** A spring stores 1 J of energy for a compression of 1 mm. The additional work to be done to compress it further by 1 mm is

(a) 1 J (b) 2 J
(c) 3 J (d) 4 J

**134.** The change in internal energy of a thermodynamical system which has absorbed 2 kcal of heat and done 400 J of work is (1 cal = 4.2 J)

(a) 2 kJ (b) 8 kJ
(c) 3.5 kJ (d) 5.5 kJ

**135.** In an air condition room, the heat exchange between the room and the space outside the room

(a) will be more when the air conditioner is off
(b) will be more rapid when the air conditioner is on
(c) will not take place at all
(d) will depend upon the floor area of the room

**136.** If internal energy of a box is U and the box is moving with some velocity, then which of the following is not to be included in U ?

(a) Kinetic energy of the box
(b) Translational kinetic energy of molecules of the gas
(c) Rotational kinetic energy of molecules of the gas
(d) Vibrational kinetic energy of the molecules of the gas

**137.** If the temperatures of source and sink of a Carnot engine having efficiency $\eta$ are each decreased by 100 K, then the efficiency

(a) remains constant (b) becomes 1
(c) decreases (d) increases

**138.** A Carnot engine takes $3 \times 10^6$ cal. of heat from a reservoir at 627°C, and gives it to a sink at 27°C. The work done by the engine is

(a) $4.2 \times 10^6$ J (b) $8.4 \times 10^6$ J
(c) $16.8 \times 10^6$ J (d) zero

**139.** A Carnot engine, having an efficiency of $\eta = 1/10$ as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is

(a) 100 J (b) 99 J
(c) 90 J (d) 1 J

**140.** A diatomic ideal gas is used in a car engine as the working substance. If during the adiabatic expansion part of the cycle, volume of the gas increases from $V$ to 32 V, the efficiency of the engine is

(a) 0.5 (b) 0.75
(c) 0.99 (d) 0.25

141. A Carnot engine operating between temperatures $T_1$ and $T_2$ has efficiency $\frac{1}{6}$. When $T_2$ is lowered by 62 K its efficiency increases to $\frac{1}{3}$. Then $T_1$ and $T_2$ are, respectively

(a) 372 K and 330 K (b) 330 K and 268 K
(c) 310 K and 248 K (d) 372 K and 310 K

142. In a Carnot engine, the temperature of reservoir is 927°C and that of sink is 27°C. If the work done by the engine when it transfers heat from reservoir to sink is $12.6 \times 10^6$ J, the quantity of heat absorbed by the engine from the reservoir is

(a) $16.8 \times 10^6$ J (b) $4 \times 10^6$ J
(c) $7.6 \times 10^6$ J (d) $4.2 \times 10^6$ J

143. The coefficient of performance of a refrigerator is 5. If the inside temperature of freezer is -20°C, then the temperature of the surroundings to which it rejects heat is

(a) 41°C (b) 11°C
(c) 21°C (d) 31°C

144. A Carnot engine, having an efficiency of $\eta = \frac{1}{10}$ as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is

(a) 99 J (b) 90 J
(c) 1 J (d) 100 J

145. A Carnot engine operating between temperatures $T_1$ and $T_2$ has efficiency 0.2. When $T_2$ is reduced by 50 K, its efficiency increases to 0.4. Then $T_1$ and $T_2$ are respectively

(a) 200 K, 150 K (b) 250 K, 200 K
(c) 300 K, 250 K (d) 300 K, 200 K

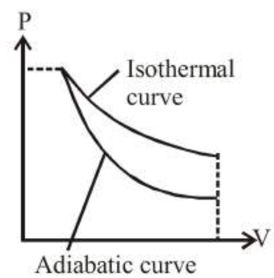
146. If the energy input to a Carnot engine is thrice the work it performs then, the fraction of energy rejected to the sink is

(a) $\frac{1}{3}$ (b) $\frac{1}{4}$
(c) $\frac{2}{5}$ (d) $\frac{2}{3}$

# HINTS AND SOLUTIONS

## FACT/DEFINITION TYPE QUESTIONS

1. (c) 2. (d) 3. (c) 4. (c)
5. (a) 6. (b) 7. (b)
8. (a) Work is energy transfer brought about by moving piston of a cylinder containing the gas, by raising or lowering some weight connected to it.
9. (d) Pressure, volume, temperature and mass are all macroscopic variables which can be measured.
10. (c) Heat and work are not state variables. They are energy, transfer to a system which change the internal energy of a system, which is a state variable.
11. (c) Internal energy of an ideal gas depends only on the temperature.
12. (c) 13. (b)
14. (a) Zeroth law defines temperature and first law defines internal energy.
15. (b)
16. (b) From FLOT $\Delta Q = \Delta U + \Delta W$
$\because$ Heat supplied to the system so
$\Delta Q \rightarrow$ Positive
and work is done on the system so
$\Delta W \rightarrow$ Negative
Hence $+\Delta Q = \Delta U - \Delta W$
17. (c)
18. (d) Heat always refers to energy transmitted from one body to another because of temperature difference.
19. (b) Internal energy and entropy are state function, they do not depend upon path but on the state.
20. (b) For one mole of a solid, the total energy.
$U = 3K_B T \times N_A = 3RT$
At constant pressure, $\Delta Q = \Delta U + P\Delta V \cong \Delta U$, since for a solid $\Delta V$ is negligible
$$\therefore \quad C = \frac{\Delta Q}{\Delta T} = \frac{\Delta U}{\Delta T} = 3R$$
21. (c) For an adiabatic process of an ideal gas.
$$PV^{\gamma} = \text{const} \qquad \text{where} \quad \gamma = \frac{C_P}{C_V}$$
22. (b) 23. (d)
24. (d) $\gamma = \dfrac{C_P}{C_V}$ & it is always larger than unity, even if gas is mono, dia or polyatomic.
$\gamma = 1.67$ monatomic gas
$\gamma = 1.40$ dia-atomic gas
$\gamma = 1.33$ polyatomic gas
25. (a) $C_p - C_v =$ work done
26. (c) In an isochoric process, no work is done on or by the gas. $V$ is constant
27. (a) 28. (c)
29. (d) R is the universal gas constant.
30. (a) In isothermal process temperature remains constnat. i.e., $\Delta T = 0$. Hence according to
$$C = \frac{Q}{m\Delta T} \Rightarrow C_{iso} = \infty$$
31. (b) In adiabatic process, no heat is taken or given by the system i.e., $\Delta Q = 0 \Rightarrow \Delta U = -\Delta W$
If $\Delta W$ is negative (work done on system), then $\Delta U$ increases & temperature increases and vice-versa. So work done in adiabatic change in particular gas (ideal gas) depends on change in temperature.
32. (a) 33. (c) 34. (a) 35. (b) 36. (c)
37. (a) From first law of thermodynamics,
$\Delta H = \Delta u + w$
In adiabatic process $\Delta H = 0$
$\therefore \quad \Delta u = -w$
38. (c) During melting temperature remains constant
39. (c)
40. (a) Every point on this isothermal curve represents the condition of a system.
41. (c) $$\frac{\text{Slope of adiabatic curve}}{\text{Slope of isothermal curve}} = \frac{(dP/dV)_{adi}}{(dP/dV)_{iso}} = +\gamma$$
So slope to adiabatic curve is $\gamma\left(=\dfrac{C_P}{C_V}\right)$ times of isothermal curve, as clear also from figure.




42. (a) 43. (c)
44. (a) In an isochoric process volume remains constant whereas pressure remains constant in isobaric process.
45. (a)

46. (a) For adiabatic process Q = 0.
By first law of thermodynamics,
Q = ΔE + W
$\Rightarrow \Delta E_{int} = -W$.

47. (c) In an adiabatic process ΔQ = 0.

48. (a) 49. (c) 50. (b)

51. (a) External amount of work must be done in order to flow heat from lower temperature to higher temperature. This is according to second law of thermodynamics.

52. (b)

53. (b)

54. (c) For process to be reversible it must be quasi-static. For quasi static process all changes take place infinitely slowly. Isothermal process occur very slowly so it is quasi-static and hence it is reversible.

55. (a) Slow isothermal expansion or compression of an ideal gas is reversible process, while the other given processes are irreversible in nature.

56. (d) In reversible cyclic Process
ΔU = 0

57. (d) Efficiency $\eta = \frac{W}{\theta_1}$ and $W = \theta_1 - \theta_2$

$\therefore \quad \eta = \frac{\theta_1 - \theta_2}{\theta_1} = 1 - \frac{\theta_2}{\theta_1}$

58. (b)

59. (b)

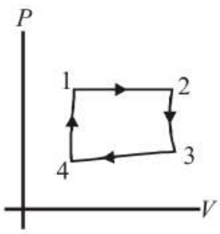
60. (d) $\eta = 1 - \frac{T_2}{T_1}$ So for η be high $T_1$ must be high and $T_2$ must be low.

61. (b)

62. (a) 63. (a)

64. (c) Absolute zero temperature is practically not reachable.

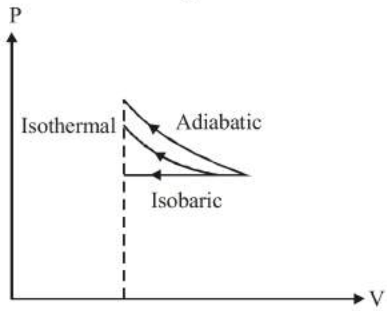
65. (b) Heat engine is device by which a system is made to undergo cyclic process that result in conversion of heat into work.




When gas (system) in heat engine undergoes process $1 \to 2 \to 3 \to 4 \to 1$, then work done by gas = area enclosed by figure formed by joining 1, 2, 3, 4.
Work is positive if arrows move clockwise.

66. (b) A thermodynamic process is reversible process can be turned back such that both the system and the surroundings return to their original states, with no other change anywhere in the universe.

67. (d) Since area under the curve is maximum for adiabatic process so, work done (W = PdV) on the gas will be maximum for adiabatic process




68. (c)

## STATEMENT TYPE QUESTIONS

69. (a)

70. (a) Specific heat of a substance does not depend on mass. It depends only on temperature and nature of the material.

71. (a) In isothermal process, the temperature remains constant so the internal energy does not change but in adiabatic process, the temperature changes and hence the internal energy also changes.

72. (c) Work done in compressing the gas increases the internal energy of the gas.

73. (c)

74. (c) is Kelvin-Planck's statement and (b) is clauss statement of second law of thermodynamics. Both the statements are completely equivalent.

75. (a) For a Carnot engine, (i) there is absolutely no friction between the walls of cylinder and the piston. (ii) Woking substance is an ideal gas. In a real engine, these conditions cannot fullfilled and hence no heat engine working between the same two temperatures can have efficiency greater than that of Carnot engine.

76. (d) 77. (c)

78. (c) Internal energy is a macroscopic state variable that depend on the state of the system not how that state is achieved. It is thermodynamic state variable.

79. (d) All the five statements are correct and so that in nature irreversibility is a rule.

## MATCHING TYPE QUESTIONS

80. (a)

| Type of processes | Feature |
|---|---|
| Isothermal | Temperature constant |
| Isobaric | Pressure constant |
| Isochoric | Volume constant |
| Adiabatic | ΔQ = 0 |

81. (a) **(A) → 3** $C_v = \frac{1}{273}$ / °C same for all gases

**(B) → 1** $PV = \cos A \Rightarrow P \propto \frac{1}{V}$

**(C) $\rightarrow$ 2** Ideal gas obey gas law at each range of temperature.

**(D) $\rightarrow$ 4** At high temperature, intermolecular forces become zero and so real gas behaves like ideal gas.

**82.** **(b)** $A \rightarrow r;\ B \rightarrow p;\ C \rightarrow q;\ D \rightarrow s$

**83.** **()** $A \rightarrow (3);\ B \rightarrow (1);\ C \rightarrow (2);\ D \rightarrow (2)$

## DIAGRAM TYPE QUESTIONS

**84.** **(a)** $\because$ Internal energy is the state function.

$\therefore$ In cyclie process; $\Delta U = 0$

According to 1st law of thermodynamics

$\boxed{\Delta Q = \Delta U + W}$

So heat absorbed

$\Delta Q = W =$ Area under the curve

$= -(2V)(P) = -2PV$

So heat rejected $= 2PV$

**85.** **(a)** Initial and final condition is same for all process

$\Delta U_1 = \Delta U_2 = \Delta U_3$

from first law of thermodynamics

$\Delta Q = \Delta U + \Delta W$

Work done

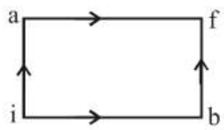
$\Delta W_1 > \Delta W_2 > \Delta W_3$ (Area of P.V. graph)

So $\Delta Q_1 > \Delta Q_2 > \Delta Q_3$

**86.** **(b)** For path iaf,

Q = 50 cal

W = 20 cal




By first law of thermodynamics,

$\Delta U = Q - W = 50 - 20 = 30$ cal.

For path ibf

$Q' = 36$ cal

$W' = ?$

or, $W' = Q' - \Delta U'$

Since, the change in internal energy does not depend on the path, therefore

$\Delta U' = 30$ cal

$\therefore\ W' = Q' - \Delta U' = 36 - 30 = 6$ cal.

**87.** **(d)** Isobaric compression is represented by curve AO

Work done = area under AD

$= 2 \times 10^2 \times (3 - 1)$

$= 4 \times 10^2 = 400$ J.

**88.** **(c)**

**89.** **(b)** In *VT* graph

ab-process : Isobaric, temperature increases.

bc process : Adiabatic, pressure decreases.

cd process : Isobaric, volume decreases.

da process : Adiabatic, pressure increases.

The above processes correctly represented in *P-V* diagram (b).

**90.** **(d)** Work done by the system in the cycle

= Area under P-V curve and V-axis

$$= \frac{1}{2}(2P_0 - P_0)(2V_0 - V_0) + \left[-\left(\frac{1}{2}\right)(3P_0 - 2P_0)(2V_0 - V_0)\right]$$

$$= \frac{P_0V_0}{2} - \frac{P_0V_0}{2} = 0$$

**91.** **(b)** In cyclic process ABCA

$Q_{cycle} = W_{cycle}$

$Q_{AB} + Q_{BC} + Q_{CA} =$ ar. of $\Delta ABC$

$$+400 + 100 + Q_{C\rightarrow A} = \frac{1}{2}(2 \times 10^{-3})(4 \times 10^4)$$

$\Rightarrow\ Q_{C\rightarrow A} = -460$ J

$\Rightarrow\ Q_{A\rightarrow C} = +460$ J

**92.** **(d)** In cyclic process, change in total internal energy is zero.

$\Delta U_{cyclic} = 0$

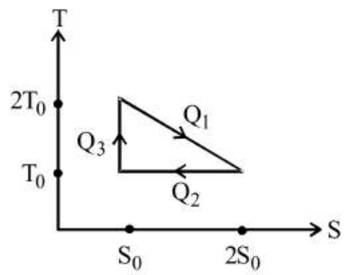
$$\Delta U_{BC} = nC_v\Delta T = 1 \times \frac{5R}{2}\Delta T$$

Where, $C_v$ = molar specific heat at constant volume.

For BC, $\Delta T = -200$ K

$\therefore\ \Delta U_{BC} = -500R$

**93.** **(d)**




$$Q_1 = T_0S_0 + \frac{1}{2}T_0S_0 = \frac{3}{2}T_0S_0$$

$$Q_2 = T_0(2S_0 - S_0) = T_0S_0 \text{ and } Q_3 = 0$$

$$\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$$

$$= 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_0S_0}{\frac{3}{2}T_0S_0} = \frac{1}{3}$$

## ASSERTION- REASON TYPE QUESTIONS

**94. (d)** Zeroth law of thermodynamics tells about thermal equilibrium.

**95. (b)** On heating a body it absorbs energy, so, its mass will increase accordingly as per the equation

$$E = mc^2$$

**96. (d)** Heat can be added to a system without increasing its temperature e.g. melting and boiling.

**97. (d)** According to first law of thermodynamics, $\Delta Q = \Delta U + \Delta W = \Delta U + P\Delta V$. If heat is supplied in such a manner that volume does not change $\Delta V = 0$, i.e., isochoric process, then whole of the heat energy supplied to the system will increase internal energy only. But, in any other process it is not possible.

Also heat may be adsorbed or evolved when state of thermal equilibrium changes.

**98. (d)** In isothermal process, $\Delta T = 0$ and so $\Delta U = 0$.

Thus $Q = 0 + W = W$.

**99. (c)** First law of thermodynamics is restatement of the principal of conservation of energy as applied to heat energy.

**100. (a)** **101. (b)** **102. (d)**

**103. (a)** The opening of bottle is the rapid or adiabatic process. In the process temperature falls.

**104. (c)** In adiabatic process, $Q = 0$

$\therefore\ 0 = \Delta U + W$ or $\Delta U = -W$.

Temperature will change in adiabatic process.

**105. (e)** As isothermal processes are very slow and so the different isothermal curves have different slopes so they cannot intersect each other.

**106. (b)** **107. (c)** **108. (a)**

**109. (d)** According to second law of thermodynamics, this is not possible to transfer heat from a body at lower temperature to a body at higher temperature without the aid of an external agent. Since, the given information produces a contradiction in second law of thermodynamics, therefore it is not possible to produce temperature of 8000 K by collecting the sun rays with a lens.

**110. (b)** When milk cools, its energy content decreases.

**111. (a)** **112. (a)** **113. (a)** **114. (a)**

**115. (a)** $\eta = 1 - \frac{T_2}{T_1}$; clearly when $T_2$ is decreases $\eta$ will increase.

**116. (a)** Carnot cycle has maximum efficiency.

## CRITICALTHINKING TYPE QUESTIONS

**117. (b)** In the first-case adiabatic change,

$\Delta Q = 0, \Delta W = -35$ J

From 1st law of thermodynamics,

$\Delta Q = \Delta U + \Delta W$,

or $\quad 0 = \Delta U - 35$

$\therefore \Delta U = 35$ J

In the second case

$\Delta Q = 12 \text{ cal} = 12 \times 4.2 \text{ J} = 50.4$ J

$\Delta W = \Delta Q - \Delta U = 50.4 - 35 = 15.4$ J

**118. (c)** According to first law of thermodynamics

$$Q = \Delta U + W$$

$$\Delta U = Q - W$$

$$= 2 \times 4.2 \times 1000 - 500$$

$$= 8400 - 500$$

$$= 7900 \text{ J}$$

**119. (b)**

$$n = \frac{PV}{RT}$$

$$= \left[\frac{1.6 \times 10^6 \times 0.0083}{8.31 \times 300}\right] = 5.33$$

$$Q = nC_v\Delta T$$

or $$2.49 \times 10^4 = 5.33 \times \left(\frac{3 \times 8.31}{2}\right) \times \Delta T$$

or $$\Delta T = 375 \text{ K}$$

$$\therefore \quad T_f = T_i + 375 = 675 \text{ K.}$$

**120. (c)** Heat required to change the temperature of vessel by a small amount $dT$

$$-dQ = mC_p dT$$

Total heat required

$$-Q = m\int_{20}^{4} 32\left(\frac{T}{400}\right)^3 dT = \frac{100 \times 10^{-3} \times 32}{(400)^3}\left[\frac{T^4}{4}\right]_{20}^{4}$$

$\Rightarrow\ Q = 0.001996$ kJ

Work done required to maintain the temperature of sink to $T_2$

$$W = Q_1 - Q_2 = \frac{Q_1 - Q_2}{Q_2} Q_2 = \left(\frac{T_1}{T_2} - 1\right) Q_2$$

$$\Rightarrow W = \left(\frac{T_1 - T_2}{T_2}\right) Q_2$$

For $T_2 = 20$ K

$$W_1 = \frac{300 - 20}{20} \times 0.001996 = 0.028 \text{ kJ}$$

For $T_2 = 4$ K

$$W_2 = \frac{300 - 4}{4} \times 0.001996 = 0.148 \text{ kJ}$$

As temperature is changing from 20k to 4 k, work done required will be more than $W_1$ but less than $W_2$.

**121. (a)** Given, $m = 4 \times 10^{-2}$ kg $= 40$ g, $\Delta T = 50°C$

Number of moles, $n = \frac{m}{M} = \frac{40}{28} = 1.43$

As nitrogen is a diatomic gas, molar specific heat at constant pressure is

$$C_p = \frac{7}{2}R = \frac{7}{2} \times 8.3 \text{Jmol}^{-1}\text{K}^{-1} = 29.05 \text{J mol}^{-1}\text{K}^{-1}$$

As $\Delta Q = nC_p\Delta T$

$\therefore \Delta Q = 1.43 \times 29.05 \times 50$

$= 2.08 \times 10^3 \text{ J} = 2.08 \text{ kJ}$

**122. (d)** Change in entropy is given by

$$dS = \frac{dQ}{T} \text{ or } \Delta S = \frac{\Delta Q}{T} = \frac{mL_f}{273}$$

$$\Delta S = \frac{1000 \times 80}{273} = 293 \text{cal/K.}$$

**123. (c)** $T_1 = 273 + 27 = 300\text{K}$

$T_2 = 273 + 927 = 1200\text{K}$

For adiabatic process,

$P^{1-\gamma} T^{\gamma} = \text{constant}$

$\Rightarrow P_1^{1-\gamma} T_1^{\gamma} = P_2^{1-\gamma} T_2^{\gamma}$

$$\Rightarrow \left(\frac{P_2}{P_1}\right)^{1-\gamma} = \left(\frac{T_1}{T_2}\right)^{\gamma}$$

$$\Rightarrow \left(\frac{P_1}{T_2}\right)^{1-\gamma} = \left(\frac{T_2}{T_1}\right)^{\gamma}$$

$$\left(\frac{P_1}{P_2}\right)^{1-1.4} = \left(\frac{1200}{300}\right)^{1.4}$$

$$\left(\frac{P_1}{P_2}\right)^{-0.4} = (4)^{1.4}$$

$$\left(\frac{P_2}{P_1}\right)^{0.4} = 4^{1.4}$$

$$P_2 = P_1\, 4^{\left(\frac{1.4}{0.4}\right)} = P_1\, 4^{\left(\frac{7}{2}\right)}$$

$= P_1 (2^7) = 2 \times 128 = 256 \text{ atm}$

**124. (b)** Initial temperature $(T_1) = 18°\text{C} = 291 \text{ K}$

Let Initial volume $(V_1) = V$

Final volume $(V_2) = \frac{V}{8}$

According to adiabatic process,

$TV^{\gamma-1} = \text{constant}$

According to question, $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$$\Rightarrow T_2 = 293\left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$\Rightarrow T_2 = 293(8)^{\frac{7}{5}-1} = 293 \times 2.297 = 668.4\text{K}$$

$\left[\text{For diatomic gas } \gamma = \frac{C_p}{C_v} = \frac{7}{5}\right]$

**125. (a)** $\Delta U = nC_v\Delta T$

$= 2 \times 10^3 \times 20 \times 273$

$= 10.9 \text{MJ.}$

**126. (c)** $P_1V_1^{\gamma} = P_2V_2^{\gamma}$ (Adiabatic change)

$$P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma} = P_1\left(\frac{V_1}{V_1/3}\right)^{\gamma} = P_2(3)^{\gamma}$$

**127. (a)** Here, $T_1 = 500 \text{ K}, T_2 = 375 \text{ K}$

$Q_1 = 25 \times 10^5 \text{ J}$

$$\therefore \eta = 1 - \frac{T_2}{T_1} = 1 - \frac{375}{500} = 0.25$$

$W = \eta Q = 0.25 \times 25 \times 10^5 = 6.25 \times 10^5 \text{ J}$

**128. (d)** The coefficient of performance of a refrigerator is given by

$$\alpha = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2}$$

Substituting the given values, we get

$$\frac{1}{3} = \frac{Q_2}{200 - Q_2}$$

$\Rightarrow 200 - Q_2 = 3Q_2 \Rightarrow 4Q_2 = 200$

or $Q_2 = \frac{200}{4}\text{J} = 50\text{J}$

$\therefore W = Q_1 - Q_2 = 200 \text{ J} - 50 \text{ J} = 150 \text{ J}$

**129. (b)** Here, Coefficient of performance $(\beta) = 5$

$T_1 = 27°\text{C}$

$= (27 + 273)\text{K}$

$= 300 \text{ K}$

$$\text{As, } \beta = \frac{T_2}{T_1 - T_2} \Rightarrow 5 = \frac{T_2}{300 - T_2}$$

or $1500 - 5T_2 = T_2$ or $6T_2 = 1500$

$$\therefore T_2 = \frac{1500}{6} = 250 \text{ K}$$

**130. (c)** By running a refrigerator with open door in a room. The room will get a little hotter because now compressor will do more work which in turn increases the room's temperature.

**131. (c)** The working of an air coditioner is similar to the working of a refrigerator. An air conditioner removes heat from the room, does some work and rejects the heat to the surroundings. As air conditioner is put in the middle of the room then due to continuous, external work the room will become slightly warmer.

**132. (c)** For isothermal process $P_1V_1 = P_2V_2$

$$\Rightarrow PV = P_2(2V) \Rightarrow P_2 = \frac{P}{2}$$

For adiabatic process

$$P_2V_2^\gamma = P_3V_3^\gamma$$

$$\Rightarrow \left(\frac{P}{2}\right)(2v)^\gamma = P_3 16v)^\gamma$$

$$\Rightarrow P_3 = \frac{3}{2}\left(\frac{1}{8}\right)^{5/3} = \frac{P}{64}$$

**133. (c)** As we know, energy stored in a spring

$$U = \frac{1}{2}kx^2$$

$x$ = extension (or compression) in the spring.

$k$ = spring constant of the spring

As per question, for $x = 1\text{mm} = 1 \times 10^{-3}\text{m}$

$$U = \frac{1}{2}k(1\times10^{-3}\text{m})^2 = 1\text{ J} \qquad \text{.......(i)}$$

If spring is further compressed by 1 mm then

$$U' = \frac{1}{2}k(2\times10^{-3}\text{m})^2 \qquad \text{.......(ii)}$$

Dividing eqn. (ii) by (i), we get

$$\frac{U'}{U} = 4 \text{ or } U' = 4U$$

Work done

$W = U' - U = 4U - U$

$= 3U = 3 \times 1\text{ J} = 3\text{J}$

**134. (b)** According to first law of thermodynamics

$Q = \Delta U + W$

Given : $Q = 2\text{ kcal} = 2000 \times 4.2 = 8400\text{ J}$

$W = 400\text{ J}$

$\therefore \Delta U = Q - W$

$= 8400 - 400$

$= 8000\text{ J}$

**135. (c)** The heat exchange between the air conditioned room and the space outside the room will not take place at all.

**136. (a)** Kinetic energy of box is not included in the internal energy of the gas.

**137. (d)** Efficiency, $\eta = \left(1 - \frac{T_2}{T_1}\right) \times 100$

$$\eta' = 1 - \frac{(T_2 - 100)}{(T_1 - 100)} \times 100$$

$$= \frac{(T_1 - 100 - T_2 + 100)}{T_1 - 100} \times 100$$

$$\eta' = \left(\frac{T_1 - T_2}{T_1 - 100}\right) \times 100.$$

Comparing with $\eta$ we get, the efficiency increases.

**138. (b)** $\eta = \frac{(627 + 273) - (273 + 27)}{627 + 273}$

$$= \frac{900 - 300}{900} = \frac{600}{900} = \frac{2}{3}$$

$$\text{work} = (\eta) \times \text{Heat} = \frac{2}{3} \times 3 \times 10^6 \times 4.2 \text{ J}$$

$$= 8.4 \times 10^6 \text{ J}$$

**139. (c)** The efficiency ($\eta$) of a Carnot engine and the coefficient of performance ($\beta$) of a refrigerator are related as

$$\beta = \frac{1 - \eta}{\eta}$$

Here, $\eta = \frac{1}{10}$

$$\therefore \beta = \frac{1 - \frac{1}{10}}{\left(\frac{1}{10}\right)} = 9.$$

Also, Coefficient of performance ($\beta$) is given by

$\beta = \frac{Q_2}{W}$, where $Q_2$ is the energy absorbed from the reservoir.

or, $9 = \frac{Q_2}{10}$

$\therefore Q_2 = 90$ J.

**140. (b)** The efficiency of cycle is

$$\eta = 1 - \frac{T_2}{T_1}$$

For adiabatic process

$T\,V^{\gamma-1}$ = constant

For diatomic gas $\gamma = \frac{7}{5}$

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

$$T_1 = T_2\left(\frac{V_2}{V_1}\right)^{\gamma-1}$$

$$T_1 = T_2(32)^{\frac{7}{5}-1} = T_2(2^5)^{2/5} = T_2 \times 4$$

$$T_1 = 4T_2$$

$$\therefore \quad \eta = \left(1-\frac{1}{4}\right) = \frac{3}{4} = 0.75$$

**141. (d)** $\eta_1 = 1-\frac{T_2}{T_1} \Rightarrow \frac{1}{6} = 1-\frac{T_2}{T_1} \Rightarrow \frac{T_2}{T_1} = \frac{5}{6} \ldots \text{(i)}$

$\eta_2 = 1-\frac{T_2-62}{T_1} \Rightarrow \frac{1}{3} = 1-\frac{T_2-62}{T_1} \quad \ldots\text{(ii)}$

On solving Eqs. (i) and (ii)

$T_1 = 372\text{ K}$ and $T_2 = 310\text{ K}$

**142. (a)** As we know $\eta = \frac{W}{Q_1} = 1-\frac{T_2}{T_1}$

$\Rightarrow \quad \eta = 1-\frac{300\text{K}}{1200\text{K}} = \frac{3}{4}$

$\frac{3}{4} = \frac{W}{Q_1} \Rightarrow Q_1 = W\times\frac{4}{3} \Rightarrow Q_1 = 12.6\times10^6\times\frac{4}{3}$

$Q_1 = 16.8 \times 10^6\text{J}.$

**143. (d)** Coefficient of performance,

$\text{Cop} = \frac{T_2}{T_1 - T_2}$

$5 = \frac{273-20}{T_1-(273-20)} = \frac{253}{T_1-253}$

$5T_1 - (5\times253) = 253$

$5T_1 = 253 + (5\times253) = 1518$

$\therefore T_1 = \frac{1518}{5} = 303.6$

or, $T_1 = 303.6 - 273 = 30.6 \cong 31°\text{C}$

**144. (b)** Efficiency of carnot engine

$n = 1-\frac{T_2}{T_1}$ i.e., $\frac{1}{10} = 1-\frac{T_2}{T_1}$

$\Rightarrow \quad \frac{T_2}{T_1} = 1-\frac{1}{10} = \frac{9}{10} \Rightarrow \frac{T_1}{T_2} = \frac{10}{9}$

$\therefore \quad w = Q_2 \cdot \left(\frac{T_1}{T_2}-1\right)$

i.e., $10 = Q_2\left(\frac{10}{9}-1\right)$ $10 = Q_2\left(\frac{1}{9}\right)$

$\Rightarrow Q_2 = 90\text{J}$

So, 90 J heat is absorbed at lower temperature.

**145. (b)** When efficiency of carnot engine, $\eta = 0.2$

Efficiency of a Carnot engine,

$\eta = 1-\frac{T_2}{T_1}$ or, $0.2 = 1-\frac{T_2}{T_1}$

or $\frac{T_2}{T_1} = 0.8 \quad \ldots\text{(i)}$

When $T_2$ is reduced by 50 K, its efficiency becomes 0.4

$\therefore \; 0.4 = 1-\frac{T_2-50}{T_1}$

or $\frac{T_2-50}{T_1} = 0.6 \quad \ldots\text{(ii)}$

Dividing eqn. (i) by (ii)

$\frac{T_2}{T_2-50} = \frac{0.8}{0.6} = \frac{4}{3}$

$\Rightarrow 3T_2 = 4T_2 - 200$ or $T_2 = 200\text{ K}$

From eqn. (ii), $T_1 = \frac{T_2-50}{0.6} = \frac{200-50}{0.6} = 250\text{K}$

**146. (d)** Efficiency $\eta = \frac{W_{output}}{\text{Heat}_{input}} = \frac{w}{3w} = \frac{1}{3}$

$\eta = 1-\frac{Q_2}{Q_1} = \frac{1}{3}$

$\therefore \; \frac{Q_2}{Q_1} = \frac{2}{3}$