

14.9: The First Law of Thermodynamics (Answer)

Check Your Understanding

3.1. $p_2(V_2 - V_1)$

3.2. Line 1, $\Delta E_{int} = 40J$;

line 2, $W = 50J$ and $\Delta E_{int} = 40J$;

line 3, $Q = 80J$ and $\Delta E_{int} = 40J$; and

line 4, $Q = 0$ and $\Delta E_{int} = 40J$

3.3. So that the process is represented by the curve $p = nRT/V$ on the pV plot for the evaluation of work.

3.4. $1.26 \times 10^{-3} J$.

Conceptual Questions

1. a. SE; b. ES; c. ES

3. Some of the energy goes into changing the phase of the liquid to gas.

5. Yes, as long as the work done equals the heat added there will be no change in internal energy and thereby no change in temperature. When water freezes or when ice melts while removing or adding heat, respectively, the temperature remains constant.

7. If more work is done on the system than heat added, the internal energy of the system will actually decrease.

9. The system must be in contact with a heat source that allows heat to flow into the system.

11. Isothermal processes must be slow to make sure that as heat is transferred, the temperature does not change. Even for isobaric and isochoric processes, the system must be in thermal equilibrium with slow changes of thermodynamic variables.

13. Typically C_p is greater than C_V because when expansion occurs under constant pressure, it does work on the surroundings. Therefore, heat can go into internal energy and work. Under constant volume, all heat goes into internal energy. In this example, water contracts upon heating, so if we add heat at constant pressure, work is done on the water by surroundings and therefore, C_p is less than C_V .

15. No, it is always greater than 1.

17. An adiabatic process has a change in temperature but no heat flow. The isothermal process has no change in temperature but has heat flow.

Problems

19. $p(V - b) = -c_T$ is the temperature scale desired and mirrors the ideal gas if under constant volume.

21. $V - bpT + cT^2 = 0$

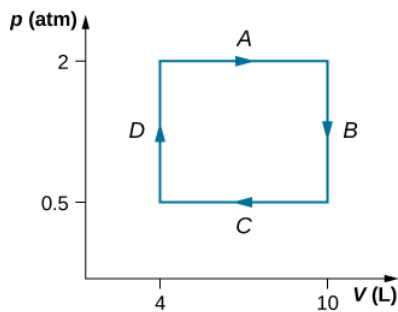
23. 74 K

25. 1.4 times

27. $pV \ln(4)$

29. a. 160 J; b. -160 J

31. $W = 900J$



33. $3.53 \times 10^4 J$

35. a. 1:1;

b. 10:1

37. a. 600 J;

b. 0;

c. 500 J;

d. 200 J;

e. 800 J;

f. 500 J

39. 580 J

41. a. 600 J;

b. 600 J;

c. 800 J

43. a. 0;

b. 160 J;

c. -160 J

45. a. 150 J;

b. 700 J

47. No work is done and they reach the same common temperature.

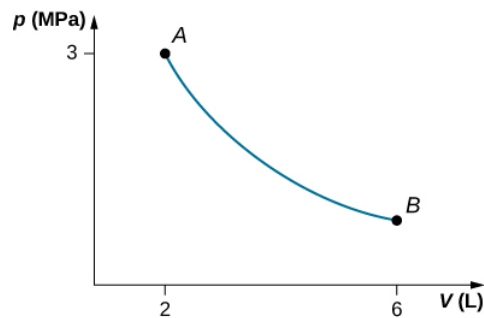
49. 54,500 J

51. a. $(p_1 + 3V_1^2)(V_2 - V_1) - 3V_1(V_2^2 - V_1^2) + (V_2^3 - V_1^3)$;

b. $\frac{3}{2}(p_2 V_2 - p_1 V_1)$;

c. the sum of parts (a) and (b); d. $T_1 = \frac{p_1 V_1}{nR}$ and $T_2 = \frac{p_2 V_2}{nR}$

53. a.



b. $W = 4.39 \text{ kJ}$, $\Delta E_{int} = -4.39 \text{ kJ}$

55. a. 1660 J;

b. -2730 J;

c. It does not depend on the process.

57. a. 700 J;

b. 500 J

59. a. -3 400 J;

b. 3400 J enters the gas

61. 100 J

63. a. 370 J;

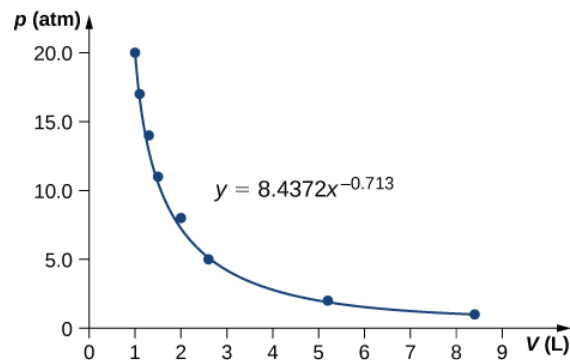
b. 100 J;

c. 500 J

65. 850 J

67. pressure decreased by 0.31 times the original pressure

69. $\gamma = 0.713$

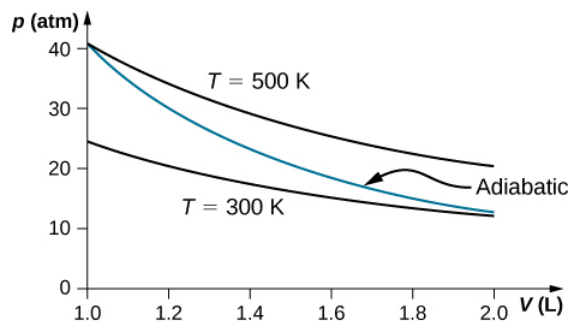


71. 84 K

73. An adiabatic expansion has less work done and no heat flow, thereby a lower internal energy comparing to an isothermal expansion which has both heat flow and work done. Temperature decreases during adiabatic expansion.

75. Isothermal has a greater final pressure and does not depend on the type of gas.

77.



Additional Problems

79. a. $W_{AB} = 0$, $W_{BC} = 2026\text{ J}$, $W_{AD} = 810.4\text{ J}$, $W_{DC} = 0$;
 b. $\Delta E_{AB} = 3600\text{ J}$, $\Delta E_{BC} = 374\text{ J}$;
 c. $\Delta E_{AC} = 3974\text{ J}$;
 d. $Q_{ADC} = 4784\text{ J}$;
 e. No, because heat was added for both parts **AD** and **DC**. There is not enough information to figure out how much is from each segment of the path.
81. 300 J
83. a. 59.5 J;
 b. 170 N
85. $2.4 \times 10^3\text{ J}$
87. a. 15,000 J;
 b. 10,000 J;
 c. 25,000 J
89. 78 J
91. A cylinder containing three moles of nitrogen gas is heated at a constant pressure of 2 atm. a. -1220 J ; b. $+1220\text{ J}$
93. a. 7.6 L, 61.6 K;
 b. 81.3 K;
 c. $3.63\text{ L} \cdot \text{atm} = 367\text{ J}$;
 d. -367 J

Challenge Problems

95. a. 1700 J; b. 1200 J; c. 2400 J
97. a. 2.2 mol;
 b. $V_A = 6.7 \times 10^{-2}\text{ m}^3$, $V_B = 3.3 \times 10^{-2}\text{ m}^3$;
 c. $T_A = 2400\text{ K}$, $T_B = 397\text{ K}$; d. 26,000 J

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