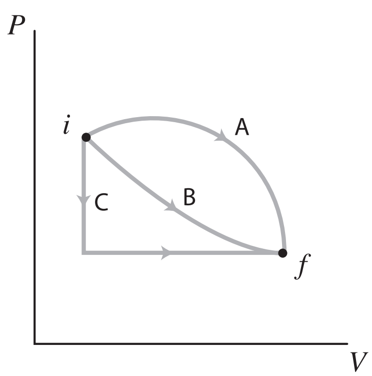
First Law of Thermodynamics Practice Items

1. The graph below show three alternative paths involving changes in the pressure and volume of an ideal gas to transform it from an initial state, *i*, to a final state, *f*. Rank the paths in order of greatest change in internal energy.

A. A > B > C
B. B > C > A
C. C > B > A
D. All three are equal.



2. The temperature is somewhat higher in the final state than the initial state in the graph above. Rank the paths in terms of the magnitude of heat flow.

A. A > B > C
B. B > C > A
C. C > B > A
D. All three are equal.

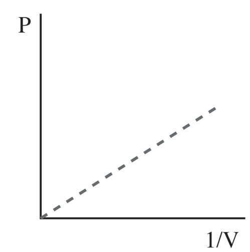
3. Which of the following must **not** be true for an isothermal compression of an ideal gas

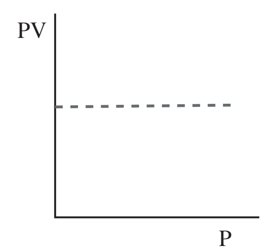
A. The work done by the surroundings on the gas equals the heat flow in magnitude.
B. Internal energy increases.
C. Gas particles have the same average kinetic energy before and after the expansion.
D. The pressure-volume product is constant.

4. An ideal gas within a well insulated container expands and does work against a piston. Which of the following provides the microscopic basis for why the gas loses internal energy?

A. Accelerating charges emit electromagnetic radiation.
B. The particle collisions with the piston are elastic.
C. A gas particle loses speed in colliding with a receding wall.
D. Temperature is proportional to the average translational kinetic energy of the particles.

5. Which of the graphs below does **not** represent an isotherm for an ideal gas?

A.


B.


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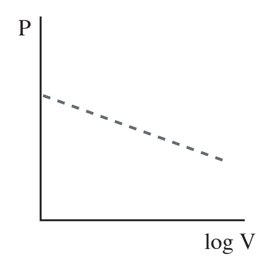

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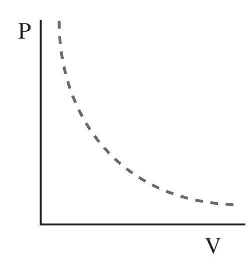
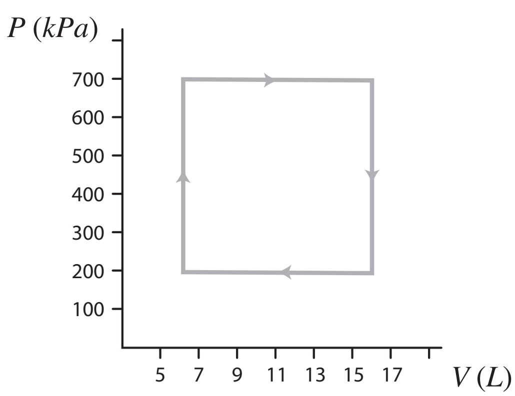


6. The heat of vaporization of water (cal/g)

A. equals the internal energy change per gram of water in transforming from liquid to gas at 1 atm of pressure.
B. is greater than the internal energy change per gram of water in transforming from liquid to gas at 1 atm of pressure.
C. equals the electrostatic potential energy increase among water molecules along lines of intermolecular force.
D. results in an increase in the kinetic energy of water vapor molecules at 100ºC compared to molecules of liquid water at 100ºC.

7. The powerful engine takes in heat both isochorically and during an isobaric expansion. Then the engine expels heat isochorically and subsequently during an isobaric compression as it returns to the initial state. The engine cycle is represented in the diagram below:



What is the difference between the heat taken en in by this engine and the heat that the engine expels each cycle?

A. 0 J
B. 50 J
C. 3500 J
D. 5000 J

8. In biochemical processes enthalpy change and internal energy change are often essentially equal because

A. most biochemical processes are isovolumetric.
B. biochemical processes are most likely to be carried out at constant pressure.
C. biochemical processes are often coupled.
D. biochemical processes are most likely to be carried out at constant temperature.

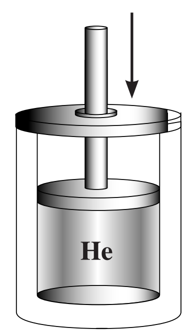
9. 1.1 L of helium at STP (C_v = 12.5 J mol^{-1} K^{-1})is compressed adiabatically until the temperature of the gas reaches 313 K. How much work was performed in the compression?

A. 25 J

B. 196 J

C. 250 J

D. 400 J



10. 2.0 mol of H_2 and 1.0 mol of O_2 react to completion at 200°C and 1 atm, producing 2.0 mol of gaseous water at 200°C and 1 atm. A total of 485kJ is evolved. How much heat evolves with the same reaction taking place at 200°C within a bomb calorimeter of fixed volume?

A. 483 kJ

B. 485 kJ

C. 487 kJ

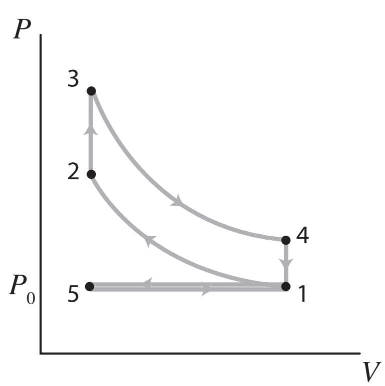
D. 507 kJ

Passage (Questions 11-16)

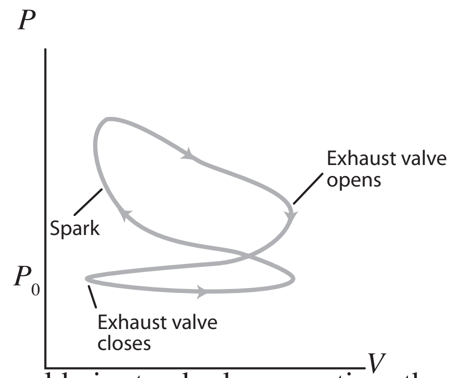
Within an internal combustion engine the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. An Otto cycle is an idealized thermodynamic cycle which describes the functioning of a typical spark ignition reciprocating piston engine, the type of internal combustion engines most commonly employed in automobiles.

To conduct elementary thermodynamic analyses of internal combustion engines, considerable simplification is required. To simplify the analysis, standard assumptions are made. Gas and air mixture are modeled as an ideal gas air-standard. All the processes making up the cycle are internally reversible. The combustion process is replaced by a heat-addition process from an external source.

On the diagram of the Otto cycle shown below, the cycle begins in state 5 with an isobaric expansion. This is followed by an adiabatic compression stroke. Heat is added in an isochoric process with the combustion of fuel, followed by an adiabatic expansion process, which characterizes the power stroke. Isochoric cooling is then followed by the exhaust stroke.



A detailed study of the performance of an actual gas power cycle is rather complex and accurate modeling of internal combustion engines normally involves computer simulation. The following diagram represents an actual internal combustion cycle. Notice that an actual cycle does not have the sharp transitions between the different processes of the ideal cycle.



Under the cold air-standard assumption, the thermal efficiency, η_{th}, of the ideal Otto cycle is

$$\eta_{th} = 1 - \frac{C_V (T_4 - T_1)}{C_V (T_3 - T_2)}$$

where C_V is the heat capacity at constant volume, and T_1, T_2 etc. are the temperatures corresponding to the various states 1,2,3 & 4 in the cycle represented in the ideal Otto cycle diagram.

We can simplify the above expression using the fact that the processes from 1 to 2 and from 3 to 4 are adiabatic.

$$\eta_{th} = 1 - \frac{1}{(V_1/V_2)^{\lambda - 1}} = 1 - \frac{1}{r^{\lambda - 1}}$$

λ is the ratio of the constant pressure heat capacity, C_P, to the heat capacity at constant volume C_V. ($\lambda_{air} = 1.4$). The term $V_1/V_2 = r$ is called the compression ratio. It is evident that the Otto cycle efficiency depends directly upon the compression ratio.

11. The exhaust and intake strokes in the Otto cycle

A. involve adiabatic compression followed by adiabatic expansion.

B. take place at constant temperature.

C. involve heat flow in an isochoric process.

D. require no net thermodynamic work.

12. An internal combustion engine with a compression ratio of 8.0 utilizes an air fuel mixture with a heat capacity ratio, C_P/C_V of 1.33. What percentage of the thermal energy produced in the combustion reaction can be transformed into useful work?

A. 16%
B. 50%
C. 75%
D. 84%

13. During the compression stroke in the Otto cycle

A. no heat flow occurs and temperature increases in the piston
B. heat flow occurs from the piston and temperature decreases
C. temperature remains constant
D. heat flow occurs into the piston and temperature increases

14. The heat of combustion is defined in chemistry as the energy released as heat flow when a compound undergoes complete combustion with oxygen under standard conditions. Assuming the complete combustion of the fuel-air mixture in an internal combustion engine, the thermal energy introduced into the piston by combustion during isochoric pressurization in the Otto cycle

A. will be greater per mole of fuel than the heat of combustion of the fuel
B. is less per mole of fuel than the heat of combustion of the fuel
C. equals the heat of combustion of the fuel
D. may be less or greater than the heat of combustion depending on the compression ratio of the engine

15. According to the assumptions underlying the Otto cycle described in the passage above, which of the following expressions represents the thermal energy liberated by fuel oxidation in the combustion chamber?

A. $C_V(T_4 - T_1)$
B. $C_V(T_3 - T_2)$
C. $C_P(T_4 - T_1)$
D. $C_V(T_4 - T_2)$

16. Which of the following may result from engineering a piston with a high compression ratio?

I. Improved engine efficiency
II. Autoignition of the fuel-vapor mix ture prior to sparking
III. A decrease in fuel-vapor density prior to sparking

A. only I
B. only II
C. I and II
D. I, II and III

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