Student #: _____ Student Name: _____

TOPIC 10: THERMODYNAMICS

1. Air is made up primarily of nitrogen and oxygen. In an enclosed room with a constant temperature, which of the following statements is correct concerning the nitrogen and oxygen gases?

   (A) The nitrogen gas molecules have a higher average kinetic energy than the oxygen gas molecules.
   (B) The nitrogen gas molecules have the same average kinetic energy as the oxygen gas molecules.
   (C) The nitrogen gas molecules have a lower average kinetic energy than the oxygen gas molecules.
   (D) More information is necessary to compare the average kinetic energies of the two gases.

2. Air is made up primarily of nitrogen and oxygen. In an enclosed room with a constant temperature, which of the following statements is correct concerning the nitrogen and oxygen gases?

   (A) The nitrogen gas molecules have a higher velocity than the oxygen gas molecules.
   (B) The nitrogen gas molecules have the same velocity as the oxygen gas molecules.
   (C) The nitrogen gas molecules have a lower velocity than the oxygen gas molecules.
   (D) It is impossible to compare the velocity of the two gases without knowing the temperature of the air and the percentage of nitrogen and oxygen in the room.

3. When using the ideal gas law, $PV = nRT$,

   (A) P can be gauge pressure
   (B) N can be in kilograms
   (C) T can be in degrees Celsius
   (D) none of the above

4. For ideal gases, the ratio PV/T is

   (A) equal to Avogadro's number
   (B) equal to Boltzmann's constant
   (C) independent of the number of molecules
   (D) independent of the chemical nature of the molecules

5. The volume of an ideal gas at constant pressure is proportional to its

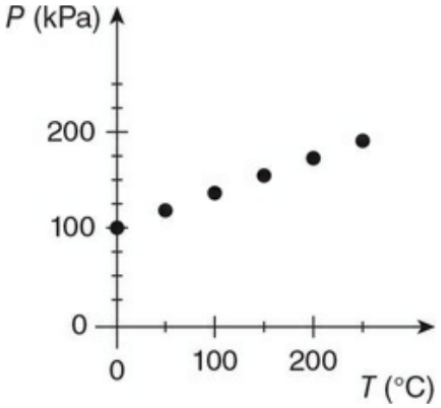
   (A) Fahrenheit temperature
   (B) Celsius temperature
   (C) Absolute temperature
   (D) Molar mass

6. In an experiment, a gas is confined in a cylinder with a movable piston. Force is applied to the piston to increase the pressure and change the volume of the gas. Each time the gas is compressed, it is allowed to return to a room temperature of 20 °C. The data gathered from the experiment is shown in the table. What should be plotted on the vertical and horizontal axes so the slope of the graph can be used to determine the number of moles of gas in the cylinder?

Pressure 10^5 Pa	**Volume** 10^{-3} m^3
1.0	25
1.5	17
1.8	14
2.2	11
2.6	9.6
3.3	7.6

   (A) P and V_2
   (B) P and V
   (C) P and $V^{1/2}$
   (D) P and $1/V$

7. In an experiment, a sealed container with a volume of 100 ml is filled with hydrogen gas. The container is heated to a variety of temperatures, and the pressure is measured. The data from the experiment is plotted in the figure. Which of the following methods can be used to determine additional information regarding the gas? Select two answers.



(A) The slope can be used to calculate the number of atoms in the gas.
(B) The area under the graph can be used to calculate the work done by the gas.
(C) The vertical axis can be used to calculate the force the gas exerts on the container.
(D) The x-intercept can be used to estimate the value of absolute zero.

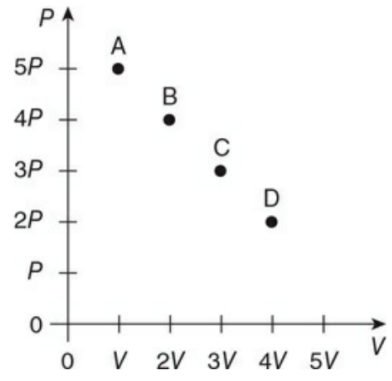
8. Two identical rooms are connected by an open door. The temperature in one room is greater than the temperature in the other. Which room contains the most gas molecules?

(A) The warmer room.
(B) The colder room.
(C) The number of gas molecules will be the same in both rooms.
(D) It is impossible to determine without more information.

9. On a hiking trip in the mountains, where the air temperature is cool and has a lower concentration of oxygen, you seal an empty water bottle. You return to your home near sea level where the air temperature is warm and has a higher concentration of oxygen. You notice that the sealed bottle appears partially crushed. Which of the following would contribute to the decrease in volume of the bottle?

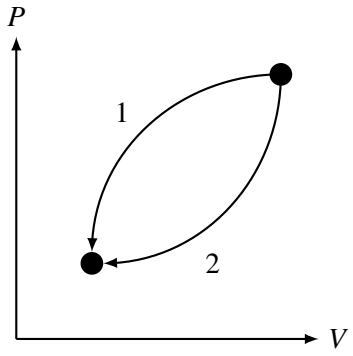
(A) The change in temperature
(B) The change in atmospheric pressure
(C) The change in oxygen concentration
(D) The change in temperature, pressure, and oxygen concentration

10. The figure shows the pressure and volume of a gas at four different states. Which of the following correctly ranks the temperature of the gas at the different states?



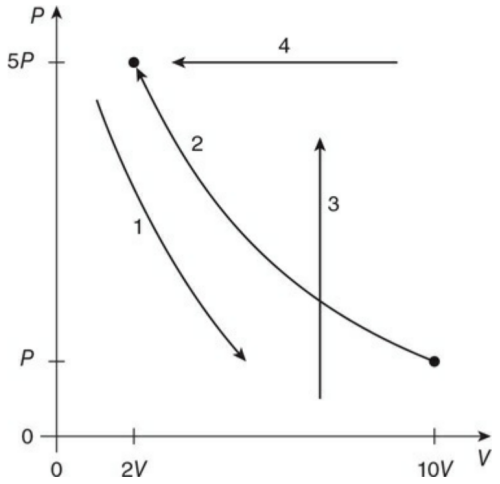
(A) $T_A > T_B > T_C > T_D$
(B) $T_B = T_C > T_A = T_D$
(C) $T_C > T_B = T_D > T_A$
(D) $T_D > T_C > T_B > T_A$

11. Which of the following is correct concerning the two processes shown in the figure?



(A) $\Delta U_1 = \Delta U_2$ and $W_1 = W_2$
(B) $\Delta U_1 = \Delta U_2$ and $W_1 > W_2$
(C) $\Delta U_1 > \Delta U_2$ and $W_1 = W_2$
(D) $\Delta U_1 > \Delta U_2$ and $W_1 \geq W_2$

12. The figure shows four samples of gas being taken through four different processes. Process 1 is adiabatic. In which process is heat being transferred to the gas sample from the environment?

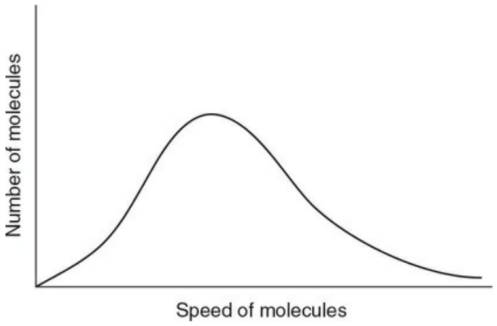


(A) 1
(B) 2
(C) 3
(D) 4

13. Two sealed cylinders holding different gases are placed one on top of the other so heat can flow between them. Cylinder A is filled with hydrogen. Cylinder B is filled with helium moving with an average speed that is half that of the hydrogen atoms. Helium atoms have four times the mass of hydrogen atoms. Which of the following best describes the transfer of heat between the two containers by conduction?

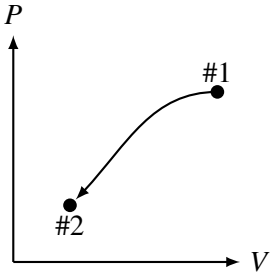
(A) Net heat flows from cylinder A to cylinder B, because heat flows from higher kinetic energy atoms to lower kinetic energy atoms.
(B) Net heat flows from cylinder B to cylinder A, because heat flows from higher kinetic energy atoms to lower kinetic energy atoms.
(C) There is no net heat transfer between the two cylinders, because both gases have the same average atomic kinetic energy.
(D) There is no net heat transfer between the two cylinders, because heat conduction requires the movement of atoms between the cylinder, and the cylinders are sealed.

14. The graph shows the distribution of speeds for one mole of hydrogen at temperature T, pressure P, and volume V. How would the graph change if the sample was changed from one mole hydrogen to one mole of argon at the same temperature, pressure, and volume?



(A) The peak will shift to the left
(B) The peak will shift upward and to the left
(C) The peak will shift to the right
(D) The peak will shift downward and to the right

15. The graph shows the pressure and volume of a gas being taken from state #1 to state #2. Which of the following correctly indicates the sign of the work done by the gas, and the change in temperature of the gas?



	Work done	**Δ Temperature**
(A)	+	+
(B)	+	−
(C)	−	+
(D)	−	−

16. A tire is filled with air at 15 °C to a gauge pressure of 2.2×10^5 Pa. If the tire reaches a temperature of 38 °C, what will the new gauge pressure be inside it?

(A) 2.4×10^2 Pa
(B) 3.4×10^3 Pa
(C) 2.4×10^5 Pa
(D) 6.0×10^7 Pa
(E) 8.0×10^9 Pa

17. A fixed mass of an ideal gas having a volume of 2500 cm^3 at 20 °C and absolute pressure of 65 atm expands until its volume is 4000 cm^3 and its absolute pressure is 45 atm. Find its new temperature.

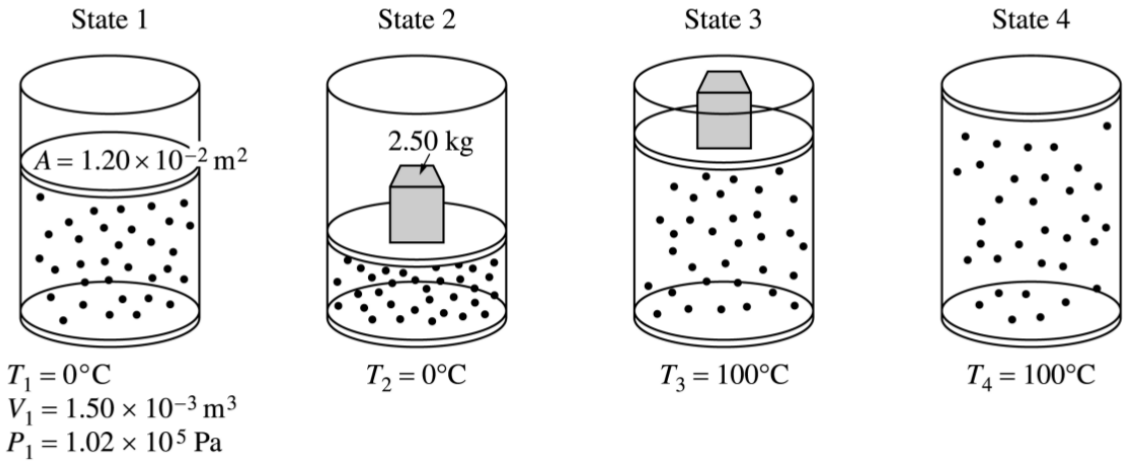
(A) 20 °C
(B) 42.3 °C
(C) 51.6 °C
(D) 61.8 °C
(E) 80 °C

18. A fixed mass of an ideal gas is in a container with a constant volume. By what factor will the pressure change if the absolute temperature is tripled?

(A) 1/9
(B) 1/3
(C) 3
(D) 9

19. If the pressure of gas is doubled and the temperature is constant, then the volume is what factor times the original?

(A) 2
(B) 1/2
(C) 1/4
(D) 4



Note: Figure not drawn to scale.

20. A cylinder is fitted with a freely movable piston of area $1.20 \times 10^{-2}\ \text{m}^2$ and negligible mass. The cylinder below the piston is filled with a gas. At state 1, the gas has volume $1.50 \times 10^{-3}\ \text{m}^3$, pressure 1.02×10^5 Pa, and the cylinder is in contact with a water bath at a temperature of 0 °C. The gas is then taken through the following four-step process.

- A 2.50 kg metal block is placed on top of the piston, compressing the gas to state 2, with the gas still at 0 °C.
- The cylinder is then brought in contact with a boiling water bath, raising the gas temperature to 100 °C at state 3.
- The metal block is removed and the gas expands to state 4 still at 100 °C.
- Finally, the cylinder is again placed in contact with the water bath at 0 °C, returning the system to state 1.

(a) Determine the pressure of the gas in state 2.

(b) Determine the volume of the gas in state 2.

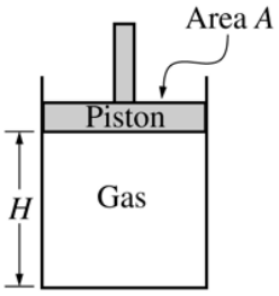
(c) Indicate below whether the process from state 2 to state 3 is isothermal, isobaric, or adiabatic. Explain your reasoning.

____ Isothermal ____ Isobaric ____ Adiabatic

(d) Is the process from state 4 to state 1 isobaric? Explain your reasoning.

____Yes ____ No

(e) Determine the volume of the gas in state 4.

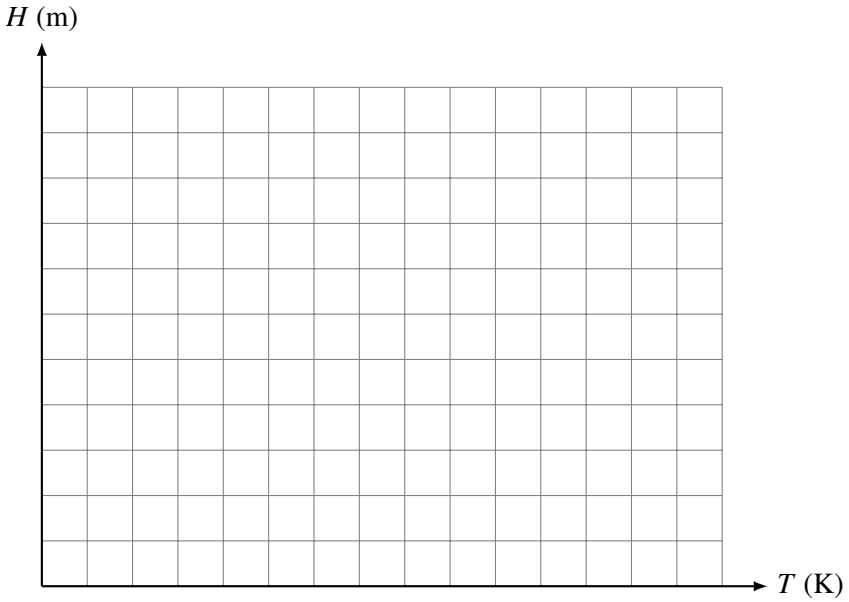


21. An experiment is performed to determine the number n of moles of an ideal gas in the cylinder shown above. The cylinder is fitted with a movable, frictionless piston of area A. The piston is in equilibrium and is supported by the pressure of the gas. The gas is heated while its pressure P remains constant. Measurements are made of the temperature T of the gas and the height H of the bottom of the piston above the base of the cylinder and are recorded in the table below. Assume that the thermal expansion of the apparatus can be ignored.

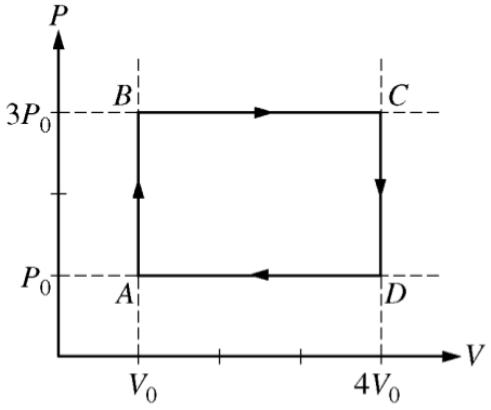
T (K)	H (m)
300	1.11
325	1.19
355	1.29
375	1.37
405	1.47

(a) Write a relationship between the quantities T and H, in terms of the given quantities and fundamental constants, that will allow you to determine n.

(b) Plot the data on the axes below so that you will be able to determine n from the relationship in part (a). Label the axes with appropriate numbers to show the scale.



(c) Using your graph and the values $A = 0.027\,\text{m}^2$ and $P = 1.0\,\text{atm}$, determine the experimental value of n.



22. A sample containing three moles of an ideal gas is taken through a series of equilibrium states, as represented by the closed path $ABCDA$ in the diagram above.

(a) i. Rank the temperatures at the 4 labeled points from least to greatest, using 1 for the lowest temperature. If two or more points have the same temperature, give them the same ranking.

____ A ____ B ____ C ____ D

ii. Determine the temperature T_D at point D in terms of P_0, V_0, and fundamental constants, as appropriate.

(b) Indicate all segments of the path $ABCDA$, if any, for which the work done by the gas is positive. If the work done by the gas is not positive for any of the segments, then check "None". Justify your answer.

____ AB ____ BC ____ CD ____ DA ____ None

(c) In process AB, is the energy transferred to the gas by heating positive, negative, or zero? Justify your answer.

____ Positive ____ Negative ____ Zero

(d) Derive an expression for the net work done on the gas during the entire process $ABCDA$. Express your answer in terms of P_0, V_0, and fundamental constants, as appropriate.

23. A cylinder with a movable piston contains 0.1 mole of a monatomic ideal gas. The gas, initially at state a, can be taken through either of two cycles, abca or abcda, as shown on the PV diagram above. The following information is known about this system.

$$Q_{c\to a} = 685\,\text{J along the curved path}$$
$$W_{c\to a} = -120\,\text{J along the curved path}$$
$$U_a - U_b = 450\,\text{J}$$
$$W_{a\to b\to c} = 75\,\text{J}$$

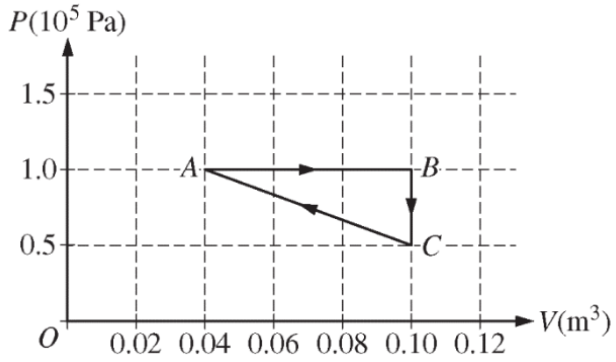
(a) Determine the change in internal energy, $U_a - U_c$, between states a and c.

(b) i. Is heat added to or removed from the gas when the gas is taken along the path abc?

ii. Calculate the amount added or removed.

(c) How much work is done on the gas in the process cda?

(d) Is heat added to or removed from the gas when the gas is taken along the path cda? Explain your reasoning.



24. Two moles of a monatomic ideal gas are enclosed in a cylinder by a movable piston. The gas is taken through the thermodynamic cycle shown in the figure above. The piston has a cross-sectional area of $5 \times 10^3\ \text{m}^2$.

(a) i. Calculate the force that the gas exerts on the piston in state A, and explain how the collisions of the gas atoms with the piston allow the gas to exert a force on the piston.

ii. Calculate the temperature of the gas in state B, and indicate the microscopic property of the gas that is characterized by the temperature.

(b) i. Predict qualitatively how the internal energy of the gas changes as it is taken from state A to state B. Justify your prediction.

ii. Calculate the energy added to the gas by heating as it is taken from state A to state C along the path ABC.

(c) Determine the change in the total kinetic energy of the gas atoms as the gas is taken directly from state C to state A.