SSSS 2018-2019
Thermodynamics

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Orlando Science High School

Exploring the World of Science

Instructions: Do not open the test until instructed to do so. This test contains two parts. Part I contains 30 multiple choice questions. Part II contains 5 free response questions. All works must be shown for part II and the final answers should be circled or boxed. All multiple choice questions are each worth 1 points while the free response questions have their own distinct values and will be shown. You may not finish the test in the allotted time of 45 minutes. (At least 5 minutes should be spent on the device **only**). Therefore, you are encouraged to complete the questions in any order that you choose. Remember to include your units, or your answer will not be scored. Tiebreaker questions are labeled Good luck ! ☺

Part I: /30	Part II: /37
Total of	
/67	
Tiebreaker Question #1:	
Tiebreaker Question #2:	

Multiple Choice:

1. Through the zeroth law of thermodynamics, which of the followings are defined?
   a. Pressure
   b. Temperature
   c. Thermal Equilibrium
   d. Work
   e. None of the above

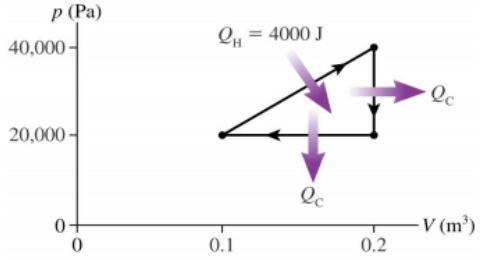
2. The same energy Q enters five different substances as heat.
   - The temperature of 3g of substance A is raised by 10K
   - The temperature of 4g of substance B is raised by 4K
   - The temperature of 6g of substance C is raised by 15K
   - The temperature of 8g of substance D is raised by 5K
   - The temperature of 10g of substance E is raised by 10K

   Which of these substances has the greatest specific heat?

   a. A
   b. B
   c. C
   d. D
   e. None of the above

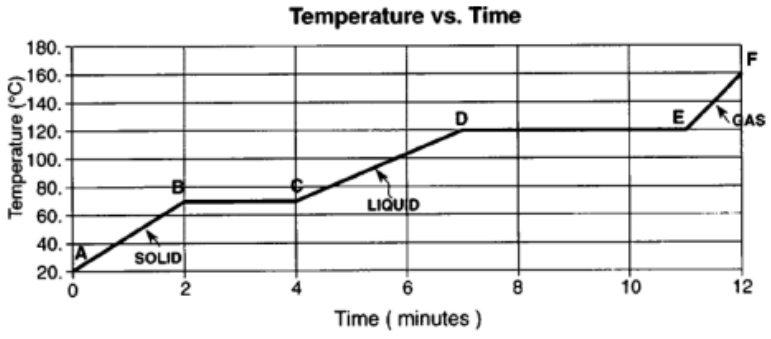
3. A quantity of an ideal gas is compressed to half its initial volume. The process may be adiabatic, isothermal, or isobaric. Rank those three processes in order of the work required of an external agent, least to greatest.
   a. Adiabatic, isothermal, isobaric
   b. Adiabatic, isobaric, isothermal
   c. Isobaric, isothermal, adiabatic
   d. Isobaric, adiabatic, isothermal
   e. None of the above

4. Determine the thermal efficiency of the given heat engine.



   a. 4
   b. 0.50
   c. 0.10
   d. 0.25
   e. None of the above

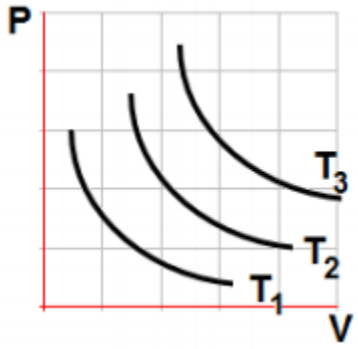
5. Base your answer on the graph below, which represents the changes in a 2.0 kilograms sample of a substance as it absorbs heat at a constant rate of 15 kilojoules per minute.



What is the specific heat of the substance in the solid phase? (All answers are in the units of kJ/kg × ℃

a. 0.22
b. 0.30
c. 0.43
d. 0.60
e. None of the above

6. A 1.00 g sample of NH_4NO_3 is decomposed in a bomb calorimeter. The temperature of the calorimeter increases by 6.12 K. The heat capacity of the system is 1.23 kJ/g℃. What is the molar heat of decomposition for ammonium nitrate?
   a. -7.53 kJ/mole
   b. -16.1 kJ/mole
   c. -398 kJ/mole
   d. -602 kJ/mole
   e. None of the above
7. Use the following diagram to answer the question given.



The state of an ideal gas was changed three times at three different temperatures. The diagram represents three different isothermal curves. Which of the following is true about the temperature of the gas?

   a. T1 > T2 > T3
   b. T1 > T2 < T3
   c. T1 < T2 < T3
   d. T1 > T2 = T3
   e. T1 = T2 > T3

8. A 45.9 g sample of a metal is heated to 95.2oC and then placed in a calorimeter containing 120.0 g of water(c = 4.18 J/goC) at 21.6oC. The final temperature of the water is 24.5oC. Which metal was used?
   a. Aluminum (c = 0.89 J/goC)
   b. Iron (c = 0.45 J/goC)
   c. Copper (c = 0.20 J/goC)
   d. Lead (c = 0.14 J/goC)
   e. None of the above
9. A 4.4-g sample of Colorado oil shale is burned in a bomb calorimeter, which causes the temperature of the calorimeter to increase by 5.0oC. The calorimeter contains 1.00 kg of water (heat capacity of H2O = 4.184 J/goC) and the heat capacity of the empty calorimeter is 0.10 kJ/oC. How much heat is released per gram of oil shale when it is burned?
   a. 21 kJ/g
   b. 42 kJ/g
   c. 0 kJ/g
   d. 4.9 kJ/g
   e. 0.21 kJ/g
10. Given the equation $S(s)+O_2(g) \longrightarrow SO_2(g), \Delta H=-296$ kJ, which of the following statement(s) is (are) true?

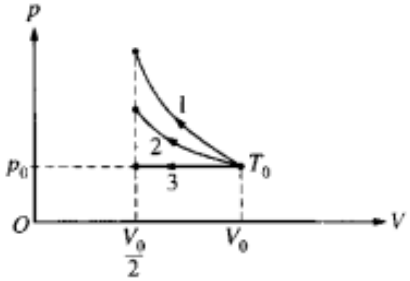
    I. The reaction is exothermic.

II. When 0.500 mole sulfur is reacted, 148 kJ of energy is released.

III. When 32.0 g of sulfur are burned, 2.96×10^5 J of energy is released.

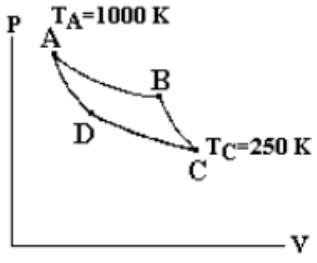
a. All are true
b. I and II are true
c. I and III are true
d. Only Ii is true
e. None of the above

Questions 11 and 12 are to be based on the given graph and information below.



A certain quantity of an ideal gas initially at temperature T_o , pressure p_0, and volume V_0 is compressed to one-half its initial volume. As shown above, the process may be adiabatic (process 1), isothermal (process 2), or isobaric (process 3).

11. Which of the following is true of mechanical work done on the gas?
    a. It is greatest for process 1.
    b. It is greatest for process 3.
    c. It is the same for process 1 and 2 and less for process 3.
    d. It is the same for process 2 and 3 and less for process 1.
    e. It is the same for all three processes.
12. Which of the following is true of the mechanical work done on the gas?
    a. It is greatest for process 1.
    b. It is greatest for process 2.
    c. It is greatest for process 3.
    d. It is the same for processes 1 and 2.
    e. It is the same for processes 1 and 3.
13. Base your answer from the given graph below.

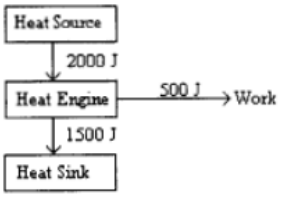


A monatomic ideal gas is used as the working substance for the Carnot cycle shown in the figure. Processes A → B and C → D are isothermal, while processes B → C and D → A are adiabatic. During process A → B, there are 400 J of work done by the gas on the surroundings.

How much heat is expelled by the gas during process C to D?

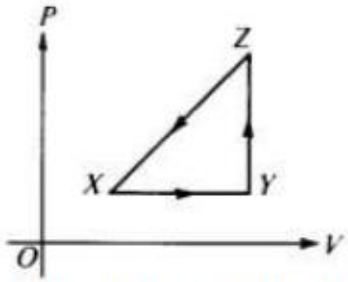
a. 1600 J
b. 800 J
c. 400 J
d. 200 J
e. 100J

14. A reversible heat engine works between a high temperature reservoir at 227°C and low temperature reservoir of 27°C. If the engine absorbs an amount of heat Q at the high temperature reservoir, how much heat will it exhaust at the low temperature reservoir?
    a. 227Q/27
    b. 27Q/227
    c. 5Q/3
    d. 3Q/5
    e. 0
15. What would be the efficiency of the heat engine diagramed as shown below?



    a. 300%
    b. 133%
    c. 75%
    d. 33%
    e. 25%

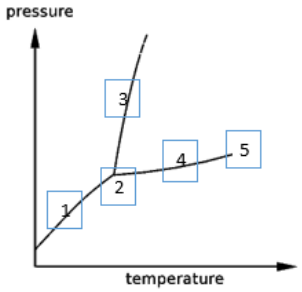
Questions 18 and 19 are to be based on the given graph and information below.



A thermodynamic system is taken from an initial state X along the path XYZX as shown in the PV-diagram.

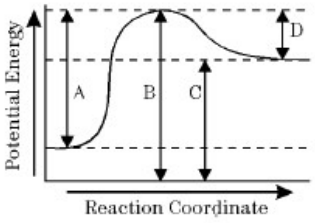
16. For the process X→Y, ΔU is greater than zero and
    a. Q<0 and W=0
    b. Q<0 and W>0
    c. Q>0 and W<0
    d. Q>0 and W=0
    e. Q>0 and W>0
17. For the process Y→Z, Q is greater than zero and
    a. W<0 and ΔU=0
    b. W=0 and ΔU<0
    c. W=0 and ΔU>0
    d. W>0 and ΔU=0
    e. W>0 and ΔU>0
18. One mole of an ideal gas expands slowly and isothermally at temperature T until its volume is doubled. The change of entropy of this gas for this process is:
    a. $(\ln 2)/T$
    b. $2R$
    c. Zero
    d. $R \ln 2$
    e. $RT \ln 2$

Questions 21 to 22 are to be based on the given graph and information below.



19. After which number will gas and liquid be indistinguishable?
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5
20. At which number does condensation occur?
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5
21. What amount of heat will change 30.0 g of ice at -40.0 °C to liquid water at 70.0 °C?
    a. 21.2 kJ
    b. 112000 J
    c. 13800J
    d. 10.0kJ
    e. 32 kJ
22. A 2.00-kg block of ice is at STP (0°C, 1 atm) while it melts completely to water. What is its change in entropy? (For ice, Lf = 3.34×10^5 J/kg)
    a. O
    a. 584 J/K
    b. 1220 J/K
    c. 2450 J/K
    d. None of the above

<u>Questions 23 and 24 refers to the following information below</u>

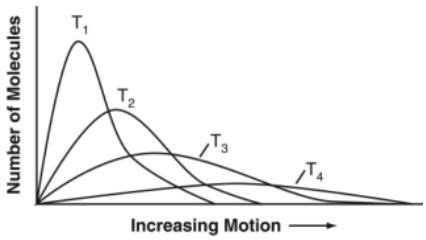


23. The forward reaction is best described as an
    a. Exothermic reaction in which energy is released
    b. Exothermic reaction in which energy is absorbed
    c. Endothermic reaction in which energy is released
    d. Endothermic reaction in which energy is absorbed
    e. None of the above
24. The following information are given:
    i. Energy gained in the reaction is 100kJ/mol
    ii. The reaction is thermodynamically favorable under the standard condition at 298K

Determine the value of $\Delta S°$ for the reaction must be

a. Equal to 0
b. Equal to $\Delta H°/298K$
c. Greater than $\Delta H°/298K$
d. Less than $\Delta H°/298K$
e. None of the above.

25. The molecular motion for a substance at four temperatures (T) is shown in the graph below.



The temperature of the substance is increasing from T_1 to T_4. What does this graph show about the relationship between temperature and molecular motion?

a. Molecular motion increases and then decreases at each temperature.
b. The number of molecules increases as the temperature increases.
c. The average molecular motion at a low temperature is greater than at a high temperature.
d. The average molecular motion increases as temperature increases.
e. None of the above

26. James Joule did much to establish the value of the
a. Universal gravitational constant
b. Speed of light
c. Mechanical equivalent of heat
d. Charge of an electron
e. Specific heat capacity of helium

27. Who determined that in the limit of absolute zero temperature, both the entropy change and the heat capacity go to zero?
a. Albert Einstein
b. James Joule
c. Lord Kelvin
d. Walther Nernst
e. James Watt

28. Who found the first version of the second law of thermodynamics based on a study of steam engines?
a. Sadi carnot
b. Rudlof Clausis
c. Clapeyron
d. Herbert Callen
e. Laszlo Tisza

29. Who introduced the caloric to remedy the flaws of phlogiston theory>
a. Sadi carnot
b. Antonie Lavoisier
c. Denis Papin
d. Thomas Newcomen
e. Joseph Pristely

30. What scale is based on theory of Carnot?
a. Celsius
b. Kelvin
c. Rankine
d. Fahrenheit
e. BTU

Short Answers:

1. Ethylene is an essential starting material in the manufacture of plastics. (3 points)

   Ethylene+Bromie gas→ Dibromoethane

   Using the table below, what is the value of ΔH of the reaction above?

Bond	Bond Energy (kJ/mol)	Bond	Bond Energy (kJ/mol)
Br – Br	193	Cl – Cl	243
C – C	347	F – F	153
C ≡ C	612	H – Br	368
C = C	820	H – Cl	431
C – Br	276	H – F	565
C – Cl	326	H – H	435
C – F	485	N – H	389
C – H	414	N – N	159
C – O	335	N = N	941
C = O	715	O – H	463

2. (a) Jungkook has a circular copper ring at 20.0 degrees Celsius which has a hole with an area of 9.980 cm^2. What is the minimum temperature that the ring must have so that it can be slipped onto a steel metal rod having a cross sectional area of 10.000 cm^2? (b) Suppose the ring and the rod are heated simultaneously. What is the minimum change in temperature of both will allow the ring to be slipped onto the end of the rod? (6 points) [Expansion coefficients of copper = $17 \times 10^{-6}°C^{-1}$, steel=$11 \times 10^{-6}°C^{-1}$] (Tiebreaker #1)

3. In a human being, a layer of fat and muscle lies under the skin having various thickness depending on the location of the body. In response and to maintain homeostasis, capillaries near the surface of the body constrict, reducing blood flow and thereby reducing the conductivity of the tissues. These tissues form a shell up to an inch thick having a thermal conductivity of about 0.21 W/(m×K), the same as skin or fat. (12 points) (Tiebreaker #2)
   (a) Estimate the rate of loss of thermal energy due to conduction from the human core region to the skin surface, assuming a shell thickness of 2.0 cm and a skin temperature of 33.0 degrees Celsius.
   (b) Calculate the thermal energy lost due to conduction in 1.0 hour.
   (c) Estimate the change in body temperature in 1.0 hour if the energy is not replenished. Assume a body mass of 75 kg and a skin surface area of 1.73m^2.

4. Draw a phase diagram and a heating curve for water. It must have all the specific points below (1/2 point per criteria. Total of 4)
    - Boiling point
    - Melting point
    - Freezing point
    - Temperatures
    - Phases / Substances at the current stage
    - Critical point/Triple point
    - Title
    - Others that scientific graph requires.

5. The star Alpha Centauri B is one member of the triple star system, Alpha Centauri AB-C, the closest start system to Earth. Given the figure below, answer the following questions (12 point) :
    (a) Calculate the power output P of Alpha Centauri B, given its surface temperature of 5,790 K and radius $R = 6.02 \times 10^8 m$.

    (b) Calculate the power P_I intercepted by a possible Earth-sized planet, Alpha Centauri Bb, with radius $r = 6.64 \times 10^6 m$, orbing its star at a distance of $r_0 = 6.00 \times 10^9 m$.

    (c) Estimate the temperature of the planet using Stefan's equation. Assume all worlds are black bodies, with e=1.

End of Assessment

Any questions or concerns should be emailed to Jaehyun Ahn through

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