



**SCIENCE OLYMPIAD**  
AT THE  
**UNIVERSITY OF FLORIDA**

Northern Regional: January 19<sup>th</sup>, 2019

# Thermodynamics C Test

**Name(s):** \_\_\_\_\_

**Team Name:** \_\_\_\_\_

**School Name:** \_\_\_\_\_

**Team Number:** \_\_\_\_\_

**Rank:** \_\_\_\_\_

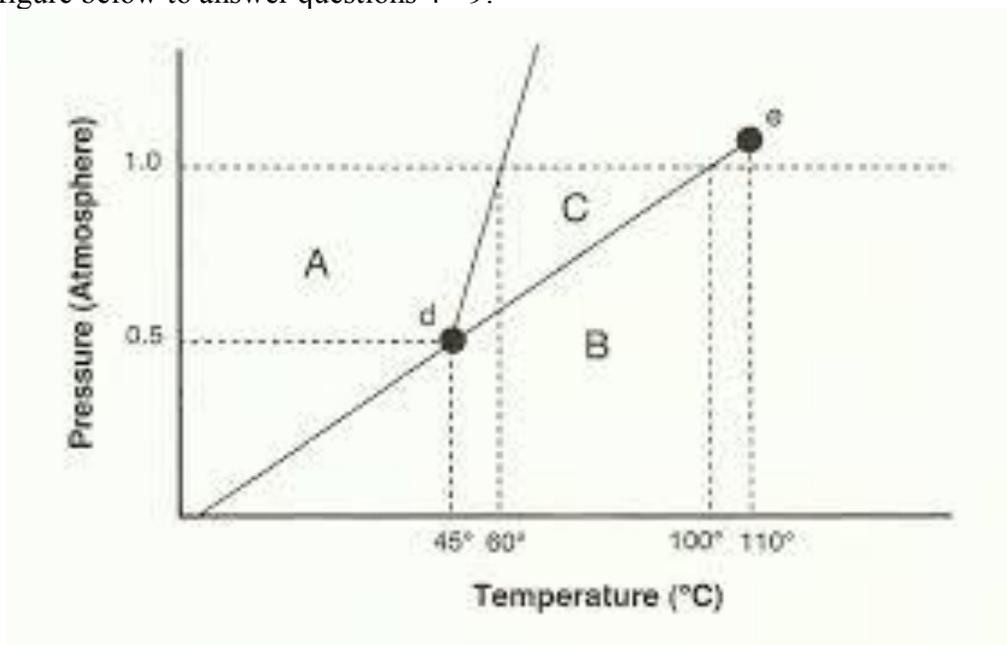
**Score:** \_\_\_\_\_

Science Olympiad North Florida Regional at the University of Florida  
Thermodynamics Division C Written Test 2019

Section 1: Multiple Choice (2 points each)

1. Who is considered to be the father of thermodynamics?
  - A. Sadi Carnot
  - B. James Watt
  - C. J. Willard Gibbs
  - D. Isaac Newton
  - E. James Joule
2. When was the first thermometer created?
  - A. 1597
  - B. 1654
  - C. 1724
  - D. 1856
3. Which one of these is no longer supported and has been replaced?
  - A. Kinetic Theory
  - B. Principle of Conservation of Mass
  - C. Caloric Theory
  - D. Principle of Conservation of Energy

Use the figure below to answer questions 4 - 9:



4. Which of the following letters corresponds to the triple point of the substance?
  - A. C
  - B. D
  - C. B
  - D. E
5. Which of the following letters corresponds to the gas phase of the substance?
  - A. A
  - B. B
  - C. C
  - D. D
6. What is the normal boiling point of the substance?
  - A. 1 atmosphere
  - B. 100 °C
  - C. 60 °C
  - D. 0.5 atmosphere
7. What is the normal melting point of the substance?
  - A. 0.5 atmosphere
  - B. 1 atmosphere
  - C. 60 °C
  - D. 100 °C

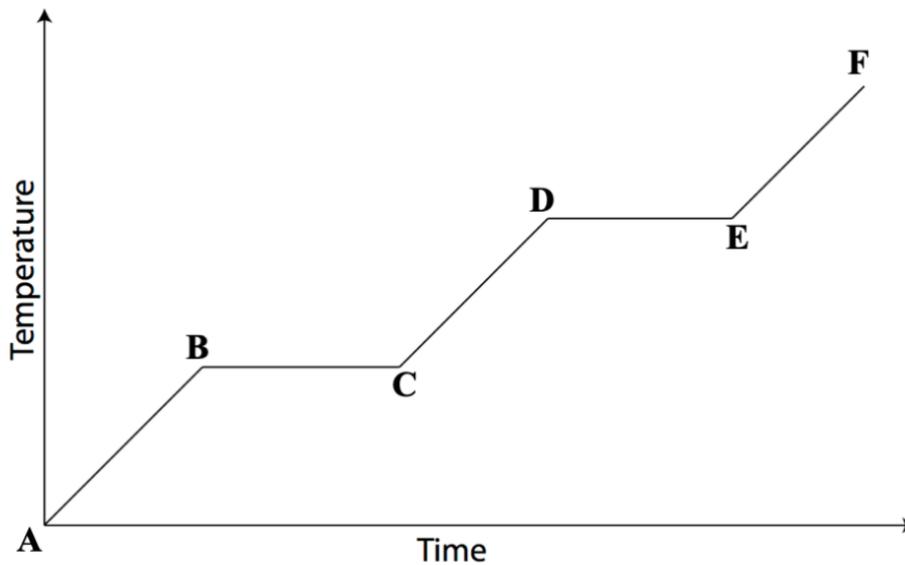
8. What process occurs when the substance moves from region A to region B?

- A. Melting/ Fusion
- B. Vaporization
- C. Deposition
- D. Sublimation

9. What process occurs when the substance moves from region B to C?

- A. Melting/ fusion
- B. Vaporization
- C. Condensation
- D. Freezing

Use the figure below to answer questions 10 - 12:



10. Which of the following segments corresponds to the liquid phase?

- A. DE
- B. BC
- C. AB
- D. CD

11. Which of the following segments corresponds to the process of freezing?

- A. B to C
- B. C to B
- C. E to D
- D. D to E

12. Which of the following segments require a latent heat?
- A. EF
  - B. AB
  - C. CD
  - D. BC
13. Which of the following phases are easily compressible?
- A. Gases
  - B. Liquids
  - C. Solids
  - D. A and B
14. How much heat is required to heat a 17 g block of ice from  $-38\text{ }^{\circ}\text{C}$  to 17 g of steam at  $113\text{ }^{\circ}\text{C}$ ? Use  $\Delta H(\text{vap})= 40.8\text{ kJ/mol}$  and  $\Delta H(\text{fus})= 6.0\text{ kJ/mol}$  and  $C(\text{ice})= 2.108\text{ J/(g }^{\circ}\text{C)}$  and  $C(\text{steam})= 1.996\text{ J/(g }^{\circ}\text{C)}$ .
- A. 804.52 kJ
  - B. 8.96 kJ
  - C. 9.71 kJ
  - D. 53.11 kJ
15. Which of the following kinds of heat transfer occurs when there is direct contact involved?
- A. Conduction
  - B. Convection
  - C. Radiation
  - D. More than one of the above
16. Which of the following kinds of heat transfer relies on heat rising?
- A. Radiation
  - B. Conduction
  - C. Convection
  - D. More than one of the above
17. What is the heat flux for a 6 m x 12 m sheet of glass that is 2 cm thick and is  $20\text{ }^{\circ}\text{C}$  on one side and  $60\text{ }^{\circ}\text{C}$  on the other side? Use  $0.96\text{ W/(m K)}$  for the thermal conductivity constant for glass.
- A.  $1920\text{ W/m}^2$
  - B.  $55.296\text{ W}$
  - C.  $0.533\text{ W/m}^3$
  - D.  $0.768\text{ W/m}^2$
18. Which one of these is not one of the steps of the Carnot Cycle?
- A. Adiabatic compression
  - B. Isothermal expansion
  - C. Isovolumetric expansion
  - D. None of the above

19. What is the efficiency of a Carnot Cycle that has temperatures of 37 °C and 63°C?
- 70.3%
  - 26.0 %
  - 58.7%
  - 41.3%
20. Which one of the following is described by a constant volume?
- Isovolumetric
  - Isobaric
  - Isochoric
  - More than one of the above
21. Which of the following statements is not part of the laws of thermodynamics?
- Two systems in thermal equilibrium with a third are in equilibrium with each other.
  - The entropy of a system approaches a constant as temperature approaches absolute zero.
  - Mass can neither be created nor destroyed.
  - The entropy of an isolated system always increases.
22. Which of the following reactions would be predicted to be spontaneous at relatively high temperatures but nonspontaneous at relatively low temperatures?
- An endothermic reaction with  $\Delta S^{\circ}_{\text{reaction}} < 0$
  - An exothermic reaction with  $\Delta S^{\circ}_{\text{reaction}} > 0$
  - An endothermic reaction with  $\Delta S^{\circ}_{\text{reaction}} > 0$
  - An exothermic reaction with  $\Delta S^{\circ}_{\text{reaction}} < 0$
23. If someone left the valve to a hydrogen gas tank open in a lab so that the partial pressures of H<sub>2</sub> and N<sub>2</sub> (in the air) in the lab both reached 0.50 atm, would the following reaction forming highly toxic liquid hydrazine (N<sub>2</sub>H<sub>4</sub>) become a concern (is the following reaction spontaneous at 25 °C given these partial pressures?)  $2\text{H}_2(\text{g}) + \text{N}_2(\text{g}) \leftrightarrow \text{N}_2\text{H}_4(\text{l})$   $\Delta G^{\circ}_{\text{reaction}} = 149 \text{ kJ/mol}$
- Yes concern because  $Q_p > K_p$  and  $\Delta G < 0$
  - No concern because  $Q_p > K_p$  and  $\Delta G > 0$
  - Yes concern because  $Q_p < K_p$  and  $\Delta G < 0$
  - No concern because  $Q_p < K_p$  and  $\Delta G > 0$
24. Which of the following statements is false?
- If  $\Delta G^{\circ} > 0$  for a reaction at some temperature, that reaction is product-favored and  $K_{\text{eq}} > 1$  at that temperature
  - If  $\Delta G > 0$ ,  $\Delta G$  represents the minimum work that must be done to the system for it to produce product(s)
  - If  $\Delta G^{\circ} = 0$ , then  $\Delta G$  can be either =0, >0, or <0
  - $\Delta G$  is based upon the difference between  $K_{\text{eq}}$  and  $Q$  of a reaction system at some temperature  $T$

25. Consider the following system which has been shown to be spontaneous at 298 K and select the true statement below:  $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$
- A.  $\Delta S_{\text{sys}} < 0$ , so  $\Delta S_{\text{surr}} > 0$  to a greater extent and  $\Delta S_{\text{univ}} > 0$ .
  - B.  $\Delta S_{\text{sys}} > 0$ , so  $\Delta S_{\text{surr}} > 0$  and  $\Delta S_{\text{univ}} > 0$ .
  - C.  $\Delta S_{\text{sys}} > 0$ , so  $\Delta S_{\text{surr}} < 0$  to a lesser extent and  $\Delta S_{\text{univ}} > 0$ .
  - D.  $\Delta S_{\text{sys}} < 0$ , so  $\Delta S_{\text{surr}} > 0$  to a lesser extent and  $\Delta S_{\text{univ}} < 0$ .
26. A spontaneous process must lead to:
- A. A net decrease in the entropy of the universe
  - B. A net increase in the entropy of the universe
  - C. A decrease in the entropy of the surroundings
  - D. An increase in the entropy of the system
27. If a reaction is non-spontaneous and  $\Delta S_{\text{sys}}^{\circ} > 0$  at 25 °C, select the true statement about the reaction.
- A.  $\Delta S_{\text{surr}} < 0$
  - B.  $\Delta S_{\text{univ}} > 0$
  - C.  $(\Delta S_{\text{sys}} + \Delta S_{\text{surr}}) > 0$
  - D. None of the above
28. Which of the following is equal to 1 kilocalorie?
- A. 4,184 kJ
  - B. 4.184 J
  - C. 4,184 J
  - D. 1000 Calories
29. 300 °C is equal to which of the following?
- A. 557.14 Romer
  - B. 26.85 Kelvin
  - C. 148.89 Fahrenheit
  - D. 1031.67 Rankine
30. What is the radiant exitance of a real surface with a temperature of 1367 K and an emissivity of 0.88?
- A.  $1.74 \times 10^5 \text{ W/m}^2$
  - B.  $1.98 \times 10^5 \text{ W/m}^2$
  - C.  $6.82 \times 10^{-5} \text{ W/m}^2$
  - D.  $7.75 \times 10^{-5} \text{ W/m}^2$

## Section 2: Free Response (7 points each)

Show all equations and calculations used to receive full credit.

31. 102.5 g of water at 65.6 °C is mixed with 102.5 g of water, already in the coffee cup calorimeter, at 18.5 °C. The final temperature of the water is 35.0 °C. Calculate the heat capacity of the calorimeter in J/ K.

32. 139 g of an unknown sample was heated to 96.4 °C and placed into a calorimeter containing 70.9 g of water at 20.0 °C. The heat capacity of the calorimeter was 12.6 J/ K. The final temperature in the calorimeter was 23.7 °C. What is the specific heat (in J/ (g °C)) of the sample?

33. When 34.2 mL of 0.500 M HCl at 25.0 °C is added to 62.4 mL of 0.500 M NaOH at 25.0 °C in a coffee-cup calorimeter, the temperature of the mixture rises to 28.2 °C. What is the heat of reaction per mole of NaCl (in kJ/ mol)? Assume the mixture has a specific heat capacity of 4.18 J/ (g K) and that the densities of the reactant solutions are both 1.07 g/ mL.

34. When 15.1 g KOH is dissolved in 100.4 g of water in a coffee-cup calorimeter, the temperature rises from 19 °C to 31.64 °C. What is the enthalpy change per gram (in J/ g) of KOH dissolved in the water?

35. In a bomb calorimeter compartment surrounded by 1.357 kg of water, the combustion of 1.351 g of benzene  $C_6H_6$  (l) raised the temperature of the water from 23.640 °C to 32.692 °C. The heat capacity of the calorimeter is 0.885 kJ/ °C. What is  $\Delta E$  for the reaction in kJ/ mol of  $C_6H_6$  (l)?

36. The standard molar entropy of vaporization ( $\Delta S^\circ_{\text{vap}}$ ) for benzene is 88 J/ (mol K) at 25 °C. Consider this information, along with the following standard molar enthalpies of formation ( $\Delta H^\circ_f$ ) for benzene at 25 °C, and estimate the normal boiling point of benzene. ( $\Delta H^\circ_f [C_6H_6$  (l)] = 49 kJ/ mol;  $\Delta H^\circ_f [C_6H_6$  (g)] = 80 kJ/ mol).