Northern Regional: January 19th, 2019

Thermodynamics C Test

Name(s): ____________________________________________

Team Name: _______________________________________

School Name: _____________________________________

Team Number: ________

Rank: _________

Score: _________
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 °C to 17 g of steam at 113 °C? Use $\Delta H(\text{vap}) = 40.8 \text{ kJ/mol}$ and $\Delta H(\text{fus}) = 6.0 \text{ kJ/mol}$ and $C(\text{ice}) = 2.108 \text{ J/(g °C)}$ and $C(\text{steam}) = 1.996 \text{ J/(g °C)}$.
   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 °C on one side and 60 °C on the other side? Use 0.96 W/(m K) for the thermal conductivity constant for glass.
   A. 1920 W/m²  
   B. 55.296 W  
   C. 0.533 W/m³  
   D. 0.768 W/m²

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?
   A. 70.3%
   B. 26.0 %
   C. 58.7%
   D. 41.3%

20. Which one of the following is described by a constant volume?
   A. Isovolumetric
   B. Isobaric
   C. Isochoric
   D. More than one of the above

21. Which of the following statements is not part of the laws of thermodynamics?
   A. Two systems in thermal equilibrium with a third are in equilibrium with each other.
   B. The entropy of a system approaches a constant as temperature approaches absolute zero.
   C. Mass can neither be created nor destroyed.
   D. 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?
   A. An endothermic reaction with $\Delta S_{\text{reaction}} < 0$
   B. An exothermic reaction with $\Delta S_{\text{reaction}} > 0$
   C. An endothermic reaction with $\Delta S_{\text{reaction}} > 0$
   D. An exothermic reaction with $\Delta S_{\text{reaction}} < 0$

23. If someone left the valve to a hydrogen gas tank open in a lab so that the partial pressures of H₂ and N₂ (in the air) in the lab both reached 0.50 atm, would the following reaction forming highly toxic liquid hydrazine (N₂H₄) become a concern? (is the following reaction spontaneous at 25 °C given these partial pressures?) $2\text{H}_2(g) + \text{N}_2(g) \leftrightarrow \text{N}_2\text{H}_4(l)$ $\Delta G_{\text{reaction}}^\circ = 149 \text{ kJ/ mol}$
   A. Yes concern because $Q_p > K_p$ and $\Delta G < 0$
   B. No concern because $Q_p > K_p$ and $\Delta G > 0$
   C. Yes concern because $Q_p < K_p$ and $\Delta G < 0$
   D. No concern because $Q_p < K_p$ and $\Delta G > 0$

24. Which of the following statements is false?
   A. If $\Delta G^\circ > 0$ for a reaction at some temperature, that reaction is product-favored and $K_{eq} > 1$ at that temperature
   B. If $\Delta G > 0$, $\Delta G$ represents the minimum work that must be done to the system for it to produce product(s)
   C. If $\Delta G^\circ = 0$, then $\Delta G$ can be either =0, >0, or <0
   D. $\Delta G$ is based upon the difference between $K_{eq}$ 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: \( N_2 + 3H_2 \rightarrow 2NH_3 \)
   A. \( \Delta S_{sys} < 0 \), so \( \Delta S_{surr} > 0 \) to a greater extent and \( \Delta S_{univ} > 0 \).
   B. \( \Delta S_{sys} > 0 \), so \( \Delta S_{surr} > 0 \) and \( \Delta S_{univ} > 0 \).
   C. \( \Delta S_{sys} > 0 \), so \( \Delta S_{surr} < 0 \) to a lesser extent and \( \Delta S_{univ} > 0 \).
   D. \( \Delta S_{sys} < 0 \), so \( \Delta S_{surr} > 0 \) to a lesser extent and \( \Delta S_{univ} < 0 \).

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 \( \Delta S_{sys} > 0 \) at 25 °C, select the true statement about the reaction.
   A. \( \Delta S_{surr} < 0 \)
   B. \( \Delta S_{univ} > 0 \)
   C. \( (\Delta S_{sys} + \Delta S_{surr}) > 0 \)
   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. \( 1.74 * 10^5 \) W/ m\(^2\)
   B. \( 1.98 * 10^5 \) W/ m\(^2\)
   C. \( 6.82 * 10^{-5} \) W/ m\(^2\)
   D. \( 7.75 * 10^{-5} \) 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 C₆H₆ (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 ΔE for the reaction in kJ/ mol of C₆H₆ (l)?

36. The standard molar entropy of vaporization (ΔS°_vap) for benzene is 88 J/ (mol K) at 25 °C. Consider this information, along with the following standard molar enthalpies of formation (ΔH°_f) for benzene at 25 °C, and estimate the normal boiling point of benzene. (ΔH°_f [C₆H₆ (l)] = 49 kJ/ mol; ΔH°_f [C₆H₆ (g)] = 80 kJ/ mol).