1. How many σ and pi bonds are in HOOCCOCH₂COOH?
   a. 10 σ, 3 π
   b. 10 σ, 5 π
   c. 12 σ, 2 π
   d. 12 σ, 3 π
   e. 7 σ, 3 π

2. Which of the following orbital overlaps is not found in pyruvic acid (CH₃COCOOH)?
   a. sp²-sp³
   b. sp²-sp²
   c. sp²-sp
   d. sp³-s
   e. p-p

3. Which of the following compounds would not be stable according to molecular orbital theory? (MO σ₂s < σ₂s* < π₂p < σ₂p < π₂p* < σ₂p*)
   a. NB²⁻
   b. NC²⁻
   c. B₂²⁺
   d. C₂²⁺
   e. N₂²⁺

4. Which of the following statements regarding molecular orbital theory is true?
   a. The average energy of a bonding MO and an antibonding MO is less than the energy of their corresponding atomic orbitals
   b. An antibonding MO is the result of in-phase addition of two atomic orbitals
   c. A σ MO could be the result of addition of “s” and “p” atomic orbitals
   d. A π MO can hold 6 electrons
   e. All of the above are false

5. What percentage of the covalent bonds in pyruvic acid (CH₃COCOOH) are free to rotate?
   a. 15%
   b. 33%
   c. 22%
   d. 78%
6. Which of the following statements regarding a $\sigma$ bond is false?
   a. A $\sigma$ bond is stronger than a $\pi$ bond
   b. A $\sigma$ bond is always between two hybridized orbitals
   c. A $\sigma$ bond always involves direct overlap between two atomic orbitals
   d. A $\sigma$ bond is free to rotate
   e. All of the above are true

7. A certain metal forms a body-centered crystal structure with edge length of 289 Å. The density of the metal is 7.14 g/cm$^3$. What is the identity of the metal?
   a. Copper
   b. Tungsten
   c. Chromium
   d. Iron
   e. Manganese

8. What phase change is undergone when going from point C to D?
   a. Melting
   b. Freezing
   c. Sublimation
   d. Condensation
   e. Deposition

9. Which of the following would cause an increase in the vapor pressure of a compound?
   I) Increasing temperature
   II) Increasing external pressure
   III) Decreasing volume of the container
   a. I only
   b. II only
   c. I and III
   d. II and III
10. Which of the following compounds has the highest boiling point?
   a. \( \text{H}_2\text{S} \)
   b. \( \text{CH}_4 \)
   c. \( \text{H}_2\text{O} \)
   d. \( \text{H}_2\text{O}_2 \)
   e. \( \text{PH}_3 \)

11. How many of the following compounds can undergo hydrogen bonding with itself?
   I) \( \text{HBr} \)
   II) \( \text{HF} \)
   III) \( (\text{CH}_3)_2\text{O} \)
   IV) \( \text{NH}_4^+ \)
   V) \( \text{CO}_2 \)
   a. 0
   b. 1
   c. 2
   d. 3
   e. 4

12. A rod made of steel is heated to 1000°C and is plunged into a bucket containing 40 liters of water at 20°C. The water boils and the system reaches an equilibrium temperature of 250°C. Assuming no heat loss to the surroundings, what is the heat capacity of the rod? (\( \Delta H_{\text{vap}}^o = 2256 \text{ J/g} \), \( \Delta H_{\text{fus}}^o = 334 \text{ J/g} \), \( c_{\text{ice}} = 2.108 \text{ J/g°C} \), \( c_{\text{water}} = 4.184 \text{ J/g°C} \), \( c_{\text{water vapor}} = 1.996 \text{ J/g°C} \))
   a. 42.1 kJ/°C
   b. 18.3 kJ/°C
   c. 51.6 kJ/°C
   d. 68.8 kJ/°C
   e. 21.1 kJ/°C

13. Which curve represents pure solvent (no solute)?

   a. A
14. Which of the following compounds would be most soluble in octane (C₈H₁₈)?
   a. NH₃
   b. PH₃
   c. H₂O
   d. CO₂
   e. NaCl

15. 20g of glucose (C₆H₁₂O₆) is added to a 500mL bottle of water. What is the boiling point of this new solution? (k_{bp} for water is .512°C/m)
   a. 100.11°C
   b. 99.89°C
   c. 111°C
   d. 89°C
   e. None of the above

16. Which of the following would increase the solubility of a gas in H₂O?
   I) Increasing temperature
   II) Increasing external pressure
   III) Decreasing volume of the container
   a. I only
   b. II only
   c. I and III
   d. II and III
   e. III only

17. A solution consists of 0.35 mol of isopropanol (C₃H₇OH) dissolved in 0.85 mol of water. What is the molarity of isopropanol in the solution? (Density of isopropanol = .785g/mL, density of water = 1g/mL)
   a. 42 mM
   b. 8.3 mM
   c. 83 mM
   d. 4.2 mM
   e. None of the above

18. 250g of benzaldehyde is added to 300mL of water. The boiling point of the solution is 104°C. What is the molar mass of benzaldehyde? (k_{bp} for water is .512°C/m)
   a. 212g/mol
   b. 106g/mol
   c. 95g/mol
   d. 18g/mol
   e. 140g/mol