I. Multiple Choice

1. Which element is a liquid at 25 °C and 1 atm pressure?
   (A) Fluorine (B) Chlorine
   (C) Bromine (D) Iodine

2. A beaker containing 25 mL of liquid 1-aminopentane, CH₃(CH₂)₄NH₂, is placed on a hotplate and brought to a boil. As the 1-aminopentane boils,
   (A) the total energy of the system stays constant.
   (B) the hydrogen bonding between the 1-aminopentane molecules is disrupted.
   (C) the ion-dipole forces between the 1-aminopentane molecules are disrupted.
   (D) pentane and ammonia gas are formed.

3. What is the principal energetic factor in the lack of miscibility between C₆H₁₄(ℓ) and H₂O(ℓ)?
   (A) The strength of intermolecular forces of attraction between C₆H₁₄(ℓ) molecules
   (B) The strength of intermolecular forces of attraction between H₂O(ℓ) molecules
   (C) The difference between the molecular weights of the molecules
   (D) The difference in electronegativity between carbon and hydrogen

4. Which compound has the highest normal boiling point?
   (A) CH₃CH₂COOH (B) CH₃CH₂CH₂OH
   (C) CH₃COOCH₃ (D) HCOOCH₂CH₃

5. Nitrogen, N₂, has the following properties:
   normal melting point: 63.2 K   normal boiling point: 77.4 K
   triple point: 0.127 atm, 63.1 K   critical point: 33.5 atm, 126.0 K

   Which statement about N₂ is correct?
   (A) Liquid N₂ is denser than solid N₂.
   (B) At sufficiently high pressure, N₂ can be liquefied at 150 K.
   (C) Liquid N₂ and gaseous N₂ can coexist at 63.1 K and 1 atm.
   (D) If N₂ is heated from 60 K to 70 K at 0.100 atm, it sublimes.

6. The vapor pressure of iodomethane, CH₃I (M = 141.9), is 110. mm Hg at 266 K. A 0.824 g sample of iodomethane is placed in a closed, evacuated 370. mL container at 266 K. At equilibrium, what will be the pressure in the container?
   (A) 96.4 mm Hg (B) 110. mm Hg
   (C) 260. mm Hg (D) 292. mm Hg

7. Which of the following properties is not typical of metallic solids?
   (A) High vapor pressure
   (B) High coordination number of atoms in the lattice
   (C) High electrical conductivity
   (D) High thermal conductivity

8. Which of the following substances experience London dispersion forces?
   I. CH₂CH₃  II. CH₃OH
   (A) I only (B) II only
   (C) Both I and II (D) Neither I nor II
9. According to the phase diagram of methanol shown below, which statement is correct?

(A) Solid methanol has a greater density than liquid methanol.
(B) Solid methanol sublimes at atmospheric pressure.
(C) Solid, liquid, and gaseous methanol can only coexist at pressures above 1 atm.
(D) At 200 ºC and 1 atm pressure, methanol is a supercritical fluid.

![Phase diagram of methanol]

10. Which of the following are ionic compounds?
   I. NH₂NO₂  II. NH₄NO₃
   (A) I only    (B) II only
   (C) Both I and II  (D) Neither I nor II

11. Which of the following statements is TRUE?
   A. Vapor pressure increases with temperature.
   B. Hydrogen bonds are stronger than covalent bonds.
   C. Intermolecular forces hold the atoms in molecules together.
   D. Dispersion forces are generally stronger than dipole-dipole forces.
   E. None of the above are true.

12. The strongest intermolecular interactions between hydrogen sulfide (H₂S) molecules arise from
   A. dipole-dipole forces.
   B. London Dispersion forces
   C. Hydrogen bonding

13. The two strands in DNA are held together by ________.
   A. dispersion forces  B. dipole-dipole forces  C. hydrogen bonding  
   D. ion-dipole forces  E. Elmer's glue

14. Place the following compounds in order of increasing strength of intermolecular forces.
   \[ \text{CH}_4 \quad \text{CH}_3\text{CH}_2\text{CH}_3 \quad \text{CH}_3\text{CH}_3 \]
   A. CH₃CH₂CH₃ < CH₄ < CH₃CH₃  B. CH₃CH₂CH₃ < CH₃CH₃ < CH₄
   C. CH₃CH₃ < CH₄ < CH₃CH₂CH₃  D. CH₄ < CH₃CH₂CH₃ < CH₃CH₃
   E. CH₄ < CH₃CH₃ < CH₃CH₂CH₃

15. In a liquid, the energy required to increase the surface of the area by a unit amount is called ________.
   A. viscosity  B. surface tension  C. capillary action  
   D. hydrogen bonding  E. Stark energy

16. Identify the term used to describe the ability of a liquid to flow against gravity up a narrow tube.
   A. capillary action  B. viscosity  C. surface tension
17. Place the following substances in order of decreasing vapor pressure at a given temperature.

\[
\text{BrF}_3 \quad \text{PF}_5 \quad \text{CF}_4
\]

A. \( \text{BrF}_3 > \text{PF}_5 > \text{CF}_4 \)  
B. \( \text{BrF}_3 > \text{CF}_4 > \text{PF}_5 \)  
C. \( \text{PF}_5 > \text{BrF}_3 > \text{CF}_4 \)  
D. \( \text{CF}_4 > \text{BrF}_3 > \text{PF}_5 \)  
E. \( \text{CF}_4 > \text{PF}_5 > \text{BrF}_3 \)

18. What mass of ice at 0.0 °C must be added to 200. g \( \text{H}_2\text{O} \) at 25.0 °C to cool it to 0.0 °C?

(A) 2.50 g  
(B) 15.0 g  
(C) 62.6 g  
(D) 200. g

II. Short Answer

1. Draw a picture of two He atoms and use words to describe the dispersion forces between the two atoms.

2. Draw a picture of two acetone molecules and use words to describe the dipole-dipole forces between the two molecules.
3. Draw a picture of two ammonia molecules and use words to describe the hydrogen bonding forces between the two molecules.

4. For each of the following pairs of molecules, list the dominant IMF for each molecule and circle the one with the higher boiling point:

   A. Ne  Ar  
   B. CF₄  CF₃O
   C. MgO  MgS
   D. \[ \text{OH} \]  \[ \text{CO} \]

5. For each of the following pairs of molecules, list the dominant IMF for each molecule and circle the one with the higher boiling point:

   A. NF₃  Na₂O
   B. PF₃  ClF₃
   C. heptane  3,3-dimethylpentane
   D.  

6. Draw a heating curve for water with “Heat Added” on the x-axis and “Temperature” on the y-axis. Label the regions according to their phases (solid, liquid, and gas) and phase transitions (solid to liquid and liquid to gas).
7. What amount of heat energy, in joules, must be removed to change 2.5 g of water vapor at 112.5°C to solid at –2.0°C? What mass of dry ice is needed to do this (see Chapter 6 HW for more info on dry ice)?

8. The following heating curve is for 97.5 g of substance with a molar mass of 54.0 g/mol. Calculate the specific heat capacity of each phase, \( \Delta H_{\text{fus}} \), and \( \Delta H_{\text{vap}} \). You will have to read information from the graph to answer this question.
9. The following data is available for the vapor pressure of nitrogen:

<table>
<thead>
<tr>
<th>Temperature (K)</th>
<th>Pressure (torr)</th>
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</thead>
<tbody>
<tr>
<td>65</td>
<td>130.5</td>
</tr>
<tr>
<td>70</td>
<td>289.5</td>
</tr>
<tr>
<td>75</td>
<td>570.8</td>
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<td>80</td>
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</tr>
<tr>
<td>85</td>
<td>1718</td>
</tr>
</tbody>
</table>

What is the heat of vaporization for nitrogen? To accomplish this, please graph the data in Excel or a similar program and use the trendline (and its equation) to determine the heat of vaporization for nitrogen. Attach your graph with the trendline.

10. Draw the setup that proves Bragg's Law, including two layers of atoms, the traveling waves of light, and the sin θ for the correct angle.

11. An X-ray beam with λ = 154 nm is incident on the surface of a crystal. The maximum reflection occurred at an angle of θ = 28.3°. Assuming n = 1, calculate the separation between layers of atoms in the crystal.
12. Draw a phase diagram for water. Label all the axes, phases, phase changes (with temperatures and pressures). Draw a horizontal line at 1 atm. For this line, draw a heating curve. Label the axes, phases, and phase transitions for the heating curve.

13. Draw a phase diagram for carbon dioxide. Label all the axes, phases, phase changes (with temperatures and pressures). Draw a horizontal line at 1 atm. For this line, draw a heating curve. Label the axes, phases, and phase transitions for the heating curve.
14. For each of the following pairs of molecules, list the dominant IMF for each molecule (2 point each) and circle the one with the higher boiling point (1 point each, only awarded if your answer is correct and both dominant IMFs are correct):

A. CH₃CH₂OH  
B. CH₃CH₂OH  
C. O₂  
D. MgO  
E. H₂O  
F. CH₄  
G. PF₅  
H. NaCl  
I. CH₃OH  
J. Ne  
K. CF₄  
L. MgO  
M. OH  
N. F₂  
O. NaCl  
P. C≡C  
Q. C≡C

NH₄Cl  
Ne  
MgCl₂  
Ne  
CF₄  
BrF₃  
HCl  

Ar  
CH₂Cl₂  
MgS  

I₂  
LiF  

F  
C≡C  
H  
H  

15. Can the acetone molecule, pictured below, hydrogen bond with another acetone molecule? Explain (your explanation can include a drawing if you want).

[Diagram of acetone molecule]

16. Can the acetone molecule, pictured below, hydrogen bond with a water molecule? Explain (your explanation can include a drawing if you want).

[Diagram of acetone molecule]