ESSAY. Write your answer in the space provided or on a separate sheet of paper.

1) Sodium hydride reacts with excess water to produce aqueous sodium hydroxide and hydrogen gas:

\[
\text{NaH (s)} + \text{H}_2\text{O (l)} \rightarrow \text{NaOH (aq)} + \text{H}_2 (\text{g})
\]

How many grams of NaH will produce 982 mL of gas at 28.0°C and 765 torr, when the hydrogen is collected over water. The vapor pressure of water at this temperature is 28 torr.
2) How much heat is required to heat 10.0 g of ice at -5.00 °C to become liquid water at 47.00 °C? In this temperature range, the specific heat of ice is 37.7 J/molK, and the specific heat of H₂O(l) is 75.8 J/molK. The molar heat of fusion of ice is 6.01 kJ/mol.

3) A sulfuric acid solution containing 571.6 g of H₂SO₄ per liter has a density of 1.329 g/cm³. Calculate the molality of the solution.
4) A closed-end manometer was attached to a vessel containing argon. The difference in the mercury levels in the two arms of the manometer was 12.2 cm. Atmospheric pressure was 783 mm Hg. The pressure of the argon in the container was ________ mm Hg.
   A) 795  B) 122  C) 661  D) 771  E) 882

5) In a Torricelli barometer, a pressure of one atmosphere supports a 760 mm column of mercury. If the original tube containing the mercury is replaced with a tube having twice the diameter of the original, the height of the mercury column at one atmosphere pressure is ________ mm.
   A) 121  B) 760  C) 1.52 \times 10^3  D) 4.78 \times 10^3  E) 380

6) A sample of gas initially at 4.00 atm was compressed from 8.00 L to 2.00 L at constant temperature. After the compression, the gas pressure was ________ atm.
   A) 16.0  B) 1.00  C) 8.00  D) 2.00  E) 4.00

7) If 50.75 g of a gas occupies 10.0 L at STP, 129.3 g of the gas will occupy ________ L at STP.
   A) 12.9  B) 5.08  C) 50.8  D) 3.92  E) 25.5

8) A sample of N\textsubscript{2} gas (2.0 mmol) effused through a pinhole in 5.5 s. It will take ________ s for the same amount of CH\textsubscript{4} to effuse under the same conditions.
   A) 3.1  B) 4.2  C) 5.5  D) 7.3  E) 9.6

9) Gaseous mixtures ________.
   A) are all homogeneous  
   B) can only contain molecules  
   C) are all heterogeneous  
   D) can only contain isolated atoms  
   E) must contain both isolated atoms and molecules

10) The pressure exerted by a column of liquid is equal to the product of the height of the column times the gravitational constant times the density of the liquid, \( P = ghd \). How high a column of water (\( d = 1.0 \text{ g/mL} \)) would be supported by a pressure that supports a 713 mm column of mercury (\( d = 13.6 \text{ g/mL} \))?
    A) 52 mm  
    B) 9.7 \times 10^3 \text{ mm}  
    C) 1.2 \times 10^4 \text{ mm}  
    D) 14 mm  
    E) 713 mm
11) Of the following, __________ is a correct statement of Boyle’s law.
   A) \( PV = \text{constant} \)
   B) \( \frac{P}{V} = \text{constant} \)
   C) \( \frac{n}{p} = \text{constant} \)
   D) \( \frac{V}{T} = \text{constant} \)
   E) \( \frac{V}{P} = \text{constant} \)

12) The volume of an ideal gas is zero at __________.
   A) -273 K    B) 0°C    C) -363 K    D) \(-273^\circ\text{C}\)    E) -45°F

13) The molar volume of a gas at STP is __________ L.
   A) 14.7    B) \(\mathbf{22.4}\)    C) 62.36    D) 1.00    E) 0.08206

14) Standard temperature and pressure (STP), in the context of gases, refers to __________.
   A) 273.15 K and 1 pascal    B) 298.15 K and 1 atm
   C) \(\mathbf{273.15 \text{ K and 1 atm}}\)    D) 298.15 K and 1 torr
   E) 273.15 K and 1 torr

15) The kinetic- molecular theory predicts that pressure rises as the temperature of a gas increases because __________.
   A) the gas molecules collide less frequently with the wall
   B) the average kinetic energy of the gas molecules decreases
   C) the gas molecules collide more energetically with the wall
   D) the gas molecules collide more frequently with the wall
   E) both the gas molecules collide more frequently with the wall and the gas molecules collide more energetically with the wall

16) A tank containing both HF and HBr gases developed a leak. The ratio of the rate of effusion of HF to the rate of effusion of HBr is __________.
   A) 4.04    B) 16.3    C) \(\mathbf{2.01}\)    D) 0.497    E) 0.247

17) Which one of the following gases would have the highest average molecular speed at \(25^\circ\text{C}\)?
   A) \(\text{O}_2\)    B) \(\text{SF}_6\)    C) \(\text{N}_2\)    D) \(\text{CO}_2\)    E) \(\text{CH}_4\)

18) A sample of oxygen gas was found to effuse at a rate equal to two times that of an unknown gas. The molecular weight of the unknown gas is __________ g/mol.
   A) 8    B) 8.0    C) 16    D) \(\mathbf{128}\)    E) 64
19) The van der Waals equation for real gases recognizes that ________.
   A) molar volumes of gases of different types are different
   B) the molecular attractions between particles of gas decreases the pressure exerted by the gas
   C) the non-zero volumes of gas particles effectively decrease the amount of “empty space”
      between them
   D) gas particles have non-zero volumes and interact with each other
   E) all of the above statements are true

20) Hydrogen bonding is a special case of ________.
   A) ion-ion interactions
   B) London-dispersion forces
   C) **dipole-dipole attractions**
   D) ion-dipole attraction
   E) none of the above

21) What type(s) of intermolecular forces exist between Br₂ and CCl₄?
   A) dispersion forces and ion-dipole
   B) dispersion forces, ion-dipole, and dipole-dipole
   C) **dispersion forces**
   D) dispersion forces and dipole-dipole
   E) None. Since both are gases at room temperature, they do not interact with each other.

22) Which statements about viscosity are true?
   (i) Viscosity increases as temperature decreases.
   (ii) Viscosity increases as molecular weight increases.
   (iii) Viscosity increases as intermolecular forces increase.
   A) (i) only
   B) (i) and (iii)
   C) (ii) and (iii)
   D) none
   E) **all**

23) Based on the following information, which compound has the strongest intermolecular forces?

<table>
<thead>
<tr>
<th>Substance</th>
<th>ΔH_vap (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon (Ar)</td>
<td>6.3</td>
</tr>
<tr>
<td>Benzene (C₆H₆)</td>
<td>31.0</td>
</tr>
<tr>
<td>Ethanol (C₂H₅OH)</td>
<td>39.3</td>
</tr>
<tr>
<td>Water (H₂O)</td>
<td>40.8</td>
</tr>
<tr>
<td>Methane (CH₄)</td>
<td>9.2</td>
</tr>
</tbody>
</table>

   A) Benzene         B) Methane       C) Ethanol       D) Argon       E) **Water**

24) Large intermolecular forces in a substance are manifested by ________.
   A) low vapor pressure
   B) high boiling point
   C) high critical temperatures and pressures
   D) high heats of fusion and vaporization
   E) **all of the above**
25) The critical temperature and pressure of \( \text{CS}_2 \) are 279\(^\circ\)C and 78 atm, respectively. At temperatures above 279\(^\circ\)C and pressures above 78 atm, \( \text{CS}_2 \) can only occur as a _________.

A) liquid and gas  
B) gas  
C) liquid  
D) **supercritical fluid**  
E) solid

26) The vapor pressure of any substance at its normal boiling point is  

A) equal to the vapor pressure of water  
B) 1 torr  
C) 1 Pa  
D) **1 atm**  
E) equal to atmospheric pressure

27) Some things take longer to cook at high altitudes than at low altitudes because _________.

A) water boils at a higher temperature at high altitude than at low altitude  
B) water **boils at a lower temperature at high altitude than at low altitude**  
C) heat isn’t conducted as well in low density air  
D) there is a higher moisture content in the air at high altitude  
E) natural gas flames don’t burn as hot at high altitudes

28) When the phase diagram for a substance has a solid-liquid phase boundary line that has a negative slope (leans to the left), the substance _________.

A) sublimes rather than melts under ordinary conditions  
B) **can go from solid to liquid, within a small temperature range, via the application of pressure**  
C) cannot go from solid to liquid by application of pressure at any temperature  
D) melts rather than sublimes under ordinary conditions  
E) cannot be liquefied above its triple point

29) Calculate the freezing point (0\(^\circ\)C) of a 0.05500 m aqueous solution of glucose. The molal freezing-point-depression constant of water is 1.86\(^\circ\)C atm.

A) -0.0562  
B) 0.106  
C) -0.204  
D) **-0.102**  
E) 0.0286

30) When argon is placed in a container of neon, the argon spontaneously disperses throughout the neon because _________.

A) of hydrogen bonding  
B) a decrease in energy occurs when the two mix  
C) of the large attractive forces between argon and neon atoms  
D) the dispersion of argon atoms produces an increase in disorder  
E) of solvent-solute interactions

31) Which one of the following substances would be the most soluble in \( \text{CCl}_4 \)?

A) \( \text{NH}_3 \)  
B) \( \text{NaCl} \)  
C) \( \text{C}_10\text{H}_{22} \)  
D) \( \text{H}_2\text{O} \)  
E) \( \text{CH}_3\text{CH}_2\text{OH} \)
32) The solubility of nitrogen gas at 25°C and 1 atm is $6.8 \times 10^{-4}$ mol/L. If the partial pressure of nitrogen gas in air is 0.76 atm, what is the concentration (molarity) of dissolved nitrogen?

A) $1.1 \times 10^{-5}$ M 
B) $6.8 \times 10^{-4}$ M 
C) $4.9 \times 10^{-4}$ M 
D) $3.8 \times 10^{-4}$ M 
E) $5.2 \times 10^{-4}$ M

33) Of the following, a 0.1 M aqueous solution of ________ will have the lowest freezing point.

A) K$_2$CrO$_4$   B) Al(NO$_3$)$_3$   C) Na$_2$SO$_4$   D) NaCl   E) sucrose