## Question #1

<table>
<thead>
<tr>
<th>Molecular View</th>
<th>State</th>
<th>Density</th>
<th>Shape</th>
<th>Volume</th>
<th>Strength of Intermolecular Forces</th>
</tr>
</thead>
<tbody>
<tr>
<td>solid</td>
<td>high</td>
<td>definite</td>
<td>definite</td>
<td></td>
<td>1 [strong, weak]</td>
</tr>
<tr>
<td>liquid</td>
<td>high</td>
<td>indefinite</td>
<td>indefinite</td>
<td>2 [definite, indefinite]</td>
<td>moderate</td>
</tr>
<tr>
<td>gas</td>
<td>(\frac{3}{low})</td>
<td>indefinite</td>
<td>indefinite</td>
<td>4 [strong, weak]</td>
<td></td>
</tr>
</tbody>
</table>
Question #: 2
Select the true statement based on this image. D is the dipole moment in Debye units.

A. Of the five listed compounds, only propane (CH₃CH₂CH₃) has intermolecular dispersion forces.
B. Since all compounds have about the same molar mass, they have about the same boiling point.
C. Acetonitrile has the greatest intermolecular dispersion forces.
D. The sum of dispersion forces and dipole-dipole attractions gives acetonitrile the strongest intermolecular attractions.

Question #: 3
Select all of the liquids in which there is intermolecular hydrogen bonding.

A. a solution of NH₃ in H₂O
B. pure acetic acid
C. pure acetone
D. pure benzene

Question #: 4
For the following liquids at the indicated temperatures, 1 (A, B, C or D) has the highest viscosity and 2 (A, B, C or D) has the lowest viscosity.

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<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CH₃CH₂CH₂CH₂CH₃</td>
<td>5 °C</td>
</tr>
<tr>
<td>B</td>
<td>CH₃CH₂CH₂CH₂CH₃</td>
<td>30°C</td>
</tr>
<tr>
<td>C</td>
<td>CH₃CH₂CH₂CH₂OH</td>
<td>5 °C</td>
</tr>
<tr>
<td>D</td>
<td>CH₃CH₂CH₂CH₂OH</td>
<td>30°C</td>
</tr>
</tbody>
</table>

1. 
2. 


**Question #**: 5
Three sets of containers are shown below with their differences noted (assume all other parameters are identical). Which container from each set will have the **lowest rate of vaporization**?

1. **Varying surface area:**

   - Conical (Erlenmeyer) flask
   - Volumetric flask
   - Round-bottom flask

   ![Images of flasks]

   - HOCH₂CH₂OH
   - C₆H₆
   - CH₃CH₂OH

2. **Varying temperature:**

   - 200 K
   - 400 K
   - 600 K

3. **Varying intermolecular forces:**

   - A. 1. Round-bottom flask
     2. 600 K
     3. C₆H₆
   - B. 1. Volumetric flask
     2. 600 K
     3. CH₃CH₂OH
   - C. 1. Volumetric flask
     2. 200 K
     3. HOCH₂CH₂OH
   - D. 1. Conical (Erlenmeyer) flask
     2. 400 K
     3. HOCH₂CH₂OH

**Question #**: 6
The normal boiling point of acetone is 56.1 °C. What is acetone's boiling point at 655 torr? The heat of vaporization, \(\Delta H_{\text{vap}}\), of acetone is 29.1 kJ/mol.

   - A. 51.6 °C
   - B. 315 °C
   - C. 56.0 °C
   - D. 16.6 °C
Question #: 7
Which of the following statements is true about the critical point in a phase diagram?
A. A liquid can exist above the critical temperature.
B. Only a supercritical fluid exists above the critical point.
C. The critical pressure is the pressure below which a solid is stable.
D. The critical point is the point at which all three phases of matter are in equilibrium.

Question #: 8
Select all of the true statement(s) below.
A. Sublimation is the phase change from liquid to gas.
B. Fusion is an endothermic process.
C. Sublimation is an exothermic process.
D. The heat of vaporization ($\Delta H_{\text{vap}}$) is greater than the heat of fusion ($\Delta H_{\text{fus}}$) for a substance.

Question #: 9
A handful of snowflakes containing 1.20 moles of water sublimes to water vapor at 0 ºC. How much heat energy was required?
At 0 ºC, $\Delta H_{\text{fus}} = 6.02$ kJ/mol and $\Delta H_{\text{vap}} = 45.1$ kJ/mol.

A. 5.55 kJ
B. 61.3 kJ
C. 47.2 kJ
D. 77.4 kJ

Question #: 10
How much energy is required to convert 15.0 g (0.832 mol) of H$_2$O(s) at −20 ºC to H$_2$O(l) at 20 ºC?
melting point = 0.00 ºC
boiling point = 100.0 ºC
$\Delta H_{\text{fus}} = 6.02$ kJ/mol
$\Delta H_{\text{vap}} = 40.7$ kJ/mol
$C_s$ of H$_2$O(s) = 2.09 J/g ºC
$C_s$ of H$_2$O(l) = 4.18 J/g ºC
$C_s$ of H$_2$O(g) = 2.01 J/g ºC

A. 6.89 kJ
B. 1860 kJ
C. 14.2 kJ
D. 26.9 kJ
Question #: 11
Consider the phase diagram shown below. At 1 atm of pressure, what phase changes occur as the temperature is raised from 100 °C to 500 °C?

A. condensation followed by vaporization
B. sublimation followed by deposition
C. fusion followed by vaporization
D. vaporization followed by deposition

Question #: 12
Fill in the appropriate number of atoms per unit cell for the following crystalline atomic solids.

A body-centered cubic unit cell contains _1_ atom(s) per unit cell.
A simple cubic unit cell contains _2_ atom(s) per unit cell.
A face-centered cubic unit cell contains _3_ atom(s) per unit cell.

1. ___________
2. ___________
3. ___________

Question #: 13
Determine the formula for the rhenium oxide shown. Rhenium ions (red circles) are located on unit cell corners. Oxide ions (blue circles) are located on unit cell edges.

A. Re₂O₃
B. Re₃O
C. ReO
D. ReO₃
**Question #**: 14
Vanadium crystallizes in a body-centered cubic unit cell with a density 6.0 g/cm³. Calculate the edge length of the unit cell.

A. $8.1 \times 10^{-24}$ cm
B. $3.0 \times 10^{-8}$ cm
C. $5.3 \times 10^{-12}$ cm
D. $7.1 \times 10^{-9}$ cm

**Question #**: 15
Which of the following is a molecular solid?

A. Cu  
B. NH₄NO₃  
C. Xe  
D. I₂

**Question #**: 16
According to band theory, a material with a large energy gap between its valence band and conduction band is a(n) _____.

1. ___

**Question #**: 17
The liquids CCl₄ and C₆H₆

A. are not miscible because they cannot form hydrogen bonds with one another.  
B. are not miscible because they are not identical, so the intermolecular interactions in the liquids are not of similar type and magnitude.  
C. are miscible because they are both polar molecules.  
D. are miscible because intermolecular interactions in the liquids are of similar type and magnitude.

**Question #**: 18
Based on the information provided by the figure below, 8.7 g of Pb(NO₃)₂ dissolved in 20.0 g H₂O at 30 °C forms a(n) _____ solution.

A. saturated  
B. supersaturated  
C. unsaturated  
D. dynamic
Question #: 19

\[ \text{[CH}_3\text{OH, C}_6\text{H}_6, \text{or NH}_3] \text{ is insoluble in water because the water-solute interactions are much } \_\_2 \text{ [}> or <] water-water plus solute-solute interactions. Enter the formula without subscripts.} \]

1. __________

2. __________

Question #: 20

The solubility of KNO\(_3\) in water is 316 g/L at 20 °C. Which statement is true?

A. A solution containing 340 g of KNO\(_3\) in 1 L of water at 20 °C is in a state of dynamic equilibrium.

B. If an additional 5 g of KNO\(_3\) are added to a solution containing 320 g of KNO\(_3\) in 1 L of water at 20 °C, the additional KNO\(_3\) will dissolve.

C. A solution containing 302 g of KNO\(_3\) in 1 L of water at 20 °C is saturated.

D. A solution containing 335 g of KNO\(_3\) in 1 L of water at 20 °C is supersaturated.

Question #: 21

At 25 ºC and a partial pressure of 0.020 atm NH\(_3\), the concentration of ammonia in water is 1.16 M. What partial pressure of ammonia is required to increase the concentration of dissolved NH\(_3\) to 2.00 M at 25 ºC?

A. 0.016 atm

B. 0.028 atm

C. 0.042 atm

D. 0.034 atm

Question #: 22

A 0.11 \(m\) aqueous solution of sucrose (C\(_{12}\)H\(_{22}\)O\(_{11}\), 342.30 g/mol) is _1_ percent by mass sucrose.

Do not include % with your answer.

1. __________

Question #: 23

The molality of a solution prepared by dissolving 15 grams of sodium bromide in 85.0 grams of water is _1_ \(m\).

Enter your answer to two significant figures, without units and not in scientific notation.

1. __________
**Question #**: 24
A 1.00 L sample of water contains 0.0036 g of Cl\(^-\) ions and has a density of 1.02 g/mL. What is the concentration of chloride ions in ppm?

\[ \text{1 \ ppm} \]
Report your answer to 2 significant figures and do not include units.

1. ___________

---

**Question #**: 25
What is the molarity of a 15.3 \text{ m} \ \text{NH}_4\text{NO}_3 (80.05 \text{ g/mol}) solution with a density of 1.252 g/mL?

A. 8.61 M
B. 12.7 M
C. 5.12 M
D. 17.9 M

---

**Question #**: 26
For each of the following solutes, enter the expected van't Hoff factor as a whole number (integer).
- \text{NaF} \quad \text{1}
- \text{MgSO}_4 \quad \text{2}
- \text{K}_2\text{SO}_3 \quad \text{3}
- \text{C}_6\text{H}_{12}\text{O}_6 (glucose) \quad \text{4}

1. __________

2. __________

3. __________

4. __________

---

**Question #**: 27
What is the vapor pressure of a solution at 25 °C that contains 940 g of fructose (C\(_6\)H\(_{12}\)O\(_6\), 180 g/mol, nonvolatile) in 250 g of water? The vapor pressure of pure water is 24 torr at 25 °C.

\[ \text{1 \ torr} \]
Report your answer to 2 significant figures and do not include units.

1. __________
Question #: 28
What is the boiling point of a solution of 10.0 g NaCl (58.44 g/mol) in 83.0 g H₂O?
\( K_b(H_2O) = 0.512 \, ^\circ C/m \)
A. 108 °C  
B. 101 °C  
C. 98.0 °C  
D. 92.0 °C

Question #: 29
What is the molarity of a Na₃PO₄ solution that exerts an osmotic pressure of 24.2 atm at 298 K?
A. 1.18 M  
B. 0.872 M  
C. 0.624 M  
D. 0.247 M

Question #: 30
Of the aqueous solutions below, solution 1 (A, B, or C) has the highest boiling point and solution 2 (A, B, or C) has the lowest boiling point.
A. 0.02 m CaCl₂  
B. 0.01 m NaBr  
C. 0.01 m Na₃PO₄

1. __________

2. __________
Question #: 1

<table>
<thead>
<tr>
<th>Molecular View</th>
<th>State</th>
<th>Density</th>
<th>Shape</th>
<th>Volume</th>
<th>Strength of Intermolecular Forces</th>
</tr>
</thead>
<tbody>
<tr>
<td>solid</td>
<td>high</td>
<td>definite</td>
<td>definite</td>
<td></td>
<td>(1) [strong, weak]</td>
</tr>
<tr>
<td>liquid</td>
<td>high</td>
<td>indefinite</td>
<td>(2) [definite, indefinite]</td>
<td></td>
<td>moderate</td>
</tr>
<tr>
<td>gas</td>
<td>(3) [high, low]</td>
<td>indefinite</td>
<td>indefinite</td>
<td></td>
<td>(4) [strong, weak]</td>
</tr>
</tbody>
</table>

1. Strong | strong |
2. definite | definite |
3. low | low | Low | low |
4. weak | Weak | weak | Weak |

Question #: 2

Select the true statement based on this image. \(D\) is the dipole moment in Debye units.

A. Of the five listed compounds, only propane \((\text{CH}_3\text{CH}_2\text{CH}_3)\) has intermolecular dispersion forces.
B. Since all compounds have about the same molar mass, they have about the same boiling point.
C. Acetonitrile has the greatest intermolecular dispersion forces.
✓ D. The sum of dispersion forces and dipole-dipole attractions gives acetonitrile the strongest intermolecular attractions.
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Select all of the liquids in which there is intermolecular hydrogen bonding.

✓ A. a solution of NH₃ in H₂O

✓ B. pure acetic acid

C. pure acetone

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For the following liquids at the indicated temperatures, __1__ (A, B, C or D) has the highest viscosity and __2__ (A, B, C or D) has the lowest viscosity.

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<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CH₃CH₂CH₂CH₂CH₃</td>
<td>5 °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>CH₃CH₂CH₂CH₂CH₃</td>
<td>30°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>CH₃CH₂CH₂CH₂OH</td>
<td>5 °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>CH₃CH₂CH₂CH₂OH</td>
<td>30°C</td>
<td></td>
<td></td>
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1. C|C.|c|c.|_

2. B|B.|b|b.|
Question #: 5
Three sets of containers are shown below with their differences noted (assume all other parameters are identical). Which container from each set will have the lowest rate of vaporization?

1. Varying surface area:
   - Conical (Erlenmeyer) flask
   - Volumetric flask
   - Round-bottom flask

2. Varying temperature:
   - 200 K
   - 400 K
   - 600 K

3. Varying intermolecular forces:
   - HOCH₂CH₂OH
   - C₆H₆
   - CH₃CH₂OH

A. 1. Round-bottom flask
   2. 600 K
   3. C₆H₆

B. 1. Volumetric flask
   2. 600 K
   3. CH₃CH₂OH

C. 1. Volumetric flask
   2. 200 K
   3. HOCH₂CH₂OH

D. 1. Conical (Erlenmeyer) flask
   2. 400 K
   3. HOCH₂CH₂OH

Question #: 6
The normal boiling point of acetone is 56.1 ºC. What is acetone's boiling point at 655 torr? The heat of vaporization, ΔH_vap, of acetone is 29.1 kJ/mol.

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Select all of the true statement(s) below.
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A handful of snowflakes containing 1.20 moles of water sublimes to water vapor at 0 ºC. How much heat energy was required?
At 0 ºC, \(\Delta H_{\text{fus}} = 6.02 \text{ kJ/mol}\) and \(\Delta H_{\text{vap}} = 45.1 \text{ kJ/mol}\).
A. 5.55 kJ
✓ B. 61.3 kJ
C. 47.2 kJ
D. 77.4 kJ

Question #: 10
How much energy is required to convert 15.0 g (0.832 mol) of \(\text{H}_2\text{O}(s)\) at −20 ºC to \(\text{H}_2\text{O}(l)\) at 20 ºC?

\begin{align*}
\text{melting point} &= 0.00 \text{ ºC} \\
\text{boiling point} &= 100.0 \text{ ºC} \\
\Delta H_{\text{fus}} &= 6.02 \text{ kJ/mol} \\
\Delta H_{\text{vap}} &= 40.7 \text{ kJ/mol} \\
C_s \text{ of } \text{H}_2\text{O}(s) &= 2.09 \text{ J/g ºC} \\
C_s \text{ of } \text{H}_2\text{O}(l) &= 4.18 \text{ J/g ºC} \\
C_s \text{ of } \text{H}_2\text{O}(g) &= 2.01 \text{ J/g ºC}
\end{align*}
✓ A. 6.89 kJ
B. 1860 kJ
C. 14.2 kJ
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Question #: 11
Consider the phase diagram shown below. At 1 atm of pressure, what phase changes occur as the temperature is raised from 100 °C to 500 °C?

A. condensation followed by vaporization
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✓ C. fusion followed by vaporization
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Question #: 12
Fill in the appropriate number of atoms per unit cell for the following crystalline atomic solids.

A body-centered cubic unit cell contains \_1\_ atom(s) per unit cell.
A simple cubic unit cell contains \_2\_ atom(s) per unit cell.
A face-centered cubic unit cell contains \_3\_ atom(s) per unit cell.

1. 2\two\to\too
2. 1\one\on
3. 4\four\for\fore

Question #: 13
Determine the formula for the rhenium oxide shown below. Rhenium ions (red circles) are located on unit cell corners. Oxide ions (blue circles) are located on unit cell edges.

A. Re\textsubscript{2}O\textsubscript{3}
B. Re\textsubscript{3}O
C. ReO
✓ D. ReO\textsubscript{3}

Question #: 14
Vanadium crystallizes in a body-centered cubic unit cell with a density 6.0 g/cm\textsuperscript{3}. Calculate the edge length of the unit cell.

A. 8.1 \times 10\textsuperscript{-24} cm
✓ B. 3.0 \times 10\textsuperscript{-8} cm
C. 5.3 \times 10\textsuperscript{-12} cm
D. 7.1 \times 10\textsuperscript{-9} cm
Question #: 15
Which of the following is a **molecular solid**?
A. Cu  
B. NH₄NO₃  
C. Xe  
✓ D. I₂

Question #: 16
According to band theory, a material with a **large** energy gap between its valence band and conduction band is a(n) __1__.
1. insulator|insultor|insulatore|ensulator|Insulator|

Question #: 17
The liquids CCl₄ and C₆H₆
A. are not miscible because they cannot form hydrogen bonds with one another.  
B. are not miscible because they are not identical, so the intermolecular interactions in the liquids are not of similar type and magnitude.  
C. are miscible because they are both polar molecules.  
✓ D. are miscible because intermolecular interactions in the liquids are of similar type and magnitude.

Question #: 18
Based on the information provided by the figure below, 8.7 g of Pb(NO₃)₂ dissolved in 20.0 g H₂O at 30 °C forms a(n) ______ solution.

A. saturated  
B. supersaturated  
✓ C. unsaturated  
D. dynamic

Question #: 19
₁ [CH₃OH, C₆H₆, or NH₃] is insoluble in water because the water-solute interactions are much __₂__ [> or <] water-water plus solute-solute interactions. Enter the formula without subscripts.
1. C₆H₆|benzene|  
2. <
**Question #**: 20
The solubility of KNO₃ in water is 316 g/L at 20 °C. Which statement is true?

A. A solution containing 340 g of KNO₃ in 1 L of water at 20 °C is in a state of dynamic equilibrium.
B. If an additional 5 g of KNO₃ are added to a solution containing 320 g of KNO₃ in 1 L of water at 20 °C, the additional KNO₃ will dissolve.
C. A solution containing 302 g of KNO₃ in 1 L of water at 20 °C is saturated.
D. A solution containing 335 g of KNO₃ in 1 L of water at 20 °C is supersaturated.

✓ D. A solution containing 335 g of KNO₃ in 1 L of water at 20 °C is supersaturated.

---

**Question #**: 21
At 25 °C and a partial pressure of 0.020 atm NH₃, the concentration of ammonia in water is 1.16 M. What partial pressure of ammonia is required to increase the concentration of dissolved NH₃ to 2.00 M at 25 °C?

A. 0.016 atm
B. 0.028 atm
C. 0.042 atm
D. 0.034 atm

✓ D. 0.034 atm

---

**Question #**: 22
A 0.11 m aqueous solution of sucrose (C₁₂H₂₂O₁₁, 342.30 g/mol) is __ percent by mass sucrose.
Do not include % with your answer.

1. 3.6|3.7|3.5|

---

**Question #**: 23
The molality of a solution prepared by dissolving 15 grams of sodium bromide in 85.0 grams of water is __ m.
Enter your answer to two significant figures, without units and not in scientific notation.

1. 1.7|1.7 m|1.7m|

---

**Question #**: 24
A 1.00 L sample of water contains 0.0036 g of Cl⁻ ions and has a density of 1.02 g/mL. What is the concentration of chloride ions in ppm?

1 ppm
Report your answer to 2 significant figures and do not include units.

1. 3.5|3.4|3.6|

---

**Question #**: 25
What is the molality of a 15.3 m NH₄NO₃ (80.05 g/mol) solution with a density of 1.252 g/mL?

✓ A. 8.61 M
B. 12.7 M
C. 5.12 M
D. 17.9 M

7
Question #: 26
For each of the following solutes, enter the expected van’t Hoff factor as a whole number (integer).

NaF  1
MgSO₄  2
K₂SO₃  3
C₆H₁₂O₆ (glucose)  4

1. 2
2. 2
3. 3
4. 1

Question #: 27
What is the vapor pressure of a solution at 25 ºC that contains 940 g of fructose (C₆H₁₂O₆, 180 g/mol, nonvolatile) in 250 g of water?
The vapor pressure of pure water is 24 torr at 25 ºC.

1 torr

Report your answer to 2 significant figures and do not include units.

1. 17

Question #: 28
What is the boiling point of a solution of 10.0 g NaCl (58.44 g/mol) in 83.0 g H₂O?

K sát (H₂O) = 0.512 °C/m

A. 108 °C
✓ B. 101 °C
C. 98.0 °C
D. 92.0 °C

Question #: 29
What is the molarity of a Na₃PO₄ solution that exerts an osmotic pressure of 24.2 atm at 298 K?

A. 1.18 M
B. 0.872 M
C. 0.624 M
✓ D. 0.247 M

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Of the aqueous solutions below, solution ___1___ (A, B, or C) has the highest boiling point and solution ___2___ (A, B, or C) has the lowest boiling point.

A. 0.02 m CaCl₂
B. 0.01 m NaBr
C. 0.01 m Na₃PO₄

1. A | A | a | a |
2. B | B | b | b |