### 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></td>
<td>2 [high, low]</td>
<td>indefinite</td>
<td>3 [definite, indefinite]</td>
<td>moderate</td>
</tr>
<tr>
<td>gas</td>
<td>low</td>
<td>4 [definite, indefinite]</td>
<td>indefinite</td>
<td>weak</td>
<td></td>
</tr>
</tbody>
</table>

1. 
2. 
3. 
4. 

Question #: 2

Of the following compounds, \(1\) has the \textbf{highest} boiling point because it has the strongest \(2\) [fill in a type of intermolecular force] intermolecular forces in the liquid phase.

- n-hexane, C\(_6\)H\(_{14}\)
- neohexane, C\(_3\)H\(_{14}\)
- n-pentane, C\(_5\)H\(_{12}\)
- neopentane, C\(_5\)H\(_{12}\)

1. __________
2. __________

Question #: 3

Which figure shows a very strong hydrogen bond?

A.

B.

C.

D.
Question #: 4

Choose the two true statements below about surface tension.

A. Surface tension is the tendency of liquids to maximize their surface area.
B. Surface tension results from the higher potential energy of surface molecules compared to interior molecules in a liquid.
C. Generally, liquids with high surface tension also have high viscosity.
D. Surface tension is the resistance of a liquid to flow.

Question #: 5

A sample of ethanol (C\textsubscript{2}H\textsubscript{5}OH) is introduced into a sealed container. Before dynamic equilibrium is reached, the rate of condensation is _________ the rate of evaporation of ethanol.

A. less than
B. equal to
C. greater than
D. the opposite of

Question #: 6

The normal boiling point of toluene (C\textsubscript{7}H\textsubscript{8}) is 384 K. The boiling point of toluene at 1.55 atm is K.

Enter your answer as a Kelvin temperature with three significant digits and without units. The heat of vaporization, \(\Delta H\text{_{vap}}\), of toluene is 38.1 kJ/mol.

1. __________
Question #: 7

Which of the following statements is true about the critical point for a substance?

A. Only a gas exists above the critical temperature.
B. Only a supercritical fluid exists above the critical point.
C. The critical pressure is the pressure above which a liquid is stable.
D. The critical point is the point at which two phases of a substance are in equilibrium.

Question #: 8

Choose the two true statements below.

A. Melting (fusion) is an endothermic process.
B. Sublimation is an exothermic process.
C. When a solid is heated to its melting point, the temperature of the solid remains constant while the substance melts.
D. The heat of fusion of a substance is generally larger than its heat of vaporization.

Question #: 9

Which one of these phase changes is generally the most exothermic?

A. fusion
B. deposition
C. vaporization
D. sublimation
What is $\Delta H_{\text{system}}$ when 58.5 g of solid benzene, C$_6$H$_6$(s), at 5.53 °C is converted to benzene vapor, C$_6$H$_6$(g), at 80.1 °C?

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molar mass C$_6$H$_6$</td>
<td>78.11 g/mol</td>
</tr>
<tr>
<td>Melting point</td>
<td>5.53 °C</td>
</tr>
<tr>
<td>Boiling point</td>
<td>80.1 °C</td>
</tr>
<tr>
<td>$\Delta H_{\text{fus}}$</td>
<td>9.90 kJ/mol</td>
</tr>
<tr>
<td>$\Delta H_{\text{vap}}$</td>
<td>30.77 kJ/mol</td>
</tr>
<tr>
<td>$C_\text{s}$ of C$_6$H$_6$(s)</td>
<td>1.52 J/g·°C</td>
</tr>
<tr>
<td>$C_\text{s}$ of C$_6$H$_6$(l)</td>
<td>1.73 J/g·°C</td>
</tr>
<tr>
<td>$C_\text{s}$ of C$_6$H$_6$(g)</td>
<td>1.06 J/g·°C</td>
</tr>
</tbody>
</table>

A. +24.2 kJ  
B. −7.70 kJ  
C. +38.0 kJ  
D. −52.1 kJ
Identify the **point** on the phase diagram or the **process** that occurs navigating between the specified points.
Decreasing the temperature at constant pressure from point C to point D. __1__
Point B. __2__
Point G. __3__
Choose from the following to fill in each blank: **solid-liquid equilibrium, solid-gas equilibrium, vaporization, condensation, triple point, critical point**

1. ___________
2. ___________
3. ___________

______________________________________________
Question #: 12

Which of these cubic unit cells has the greatest packing efficiency?

A. 

B. 

C. 

____________________________________________________________________________
Question #: 13

The formula of the ionic compound with the unit cell below is \[ \text{______}. \]
List the formula in the order Pb\# Zr\# O\#, with the lowest whole-number coefficient for each element (even if it is 1) and a space between each element.

1. \[ \text{______} \]

Question #: 14

Barium metal crystallizes in a body-centered cubic lattice, as shown below, with an edge length of 507 pm. The density of barium is \[ \text{______} \text{ g/cm}^3. \]
Report your answer with two significant digits. Do NOT include units in your answer.

1. \[ \text{______} \]
**Question #15**

Iodine, $I_2$, has a melting point of 114 °C, whereas methanol (CH$_3$OH) has a melting point of −98 °C. Why is this true?

A. Dispersion forces in iodine are stronger than dipole-dipole, hydrogen bonding, and dispersion forces in methanol.
B. Dispersion forces are always stronger than hydrogen bonding forces.
C. Iodine is a network covalent solid.
D. Ionic solids are higher melting than molecular solids.

**Question #16**

Provide a term to describe the electrical behavior of each of the materials on the band diagram below.

Figure 1 illustrates a(n) ___.
Figure 2 illustrates a(n) ___.
Figure 3 illustrates a(n) ___.

1. __________
2. __________
3. __________
Question #: 17

Benzene (C₆H₆) and n-butanol (C₄H₉OH) are miscible with one another in all proportions because

A. they form strong hydrogen bonds with one another.
B. there is a large decrease in potential energy for the mixed liquids compared to the two pure liquids.
C. there is a large increase in entropy for the mixed liquids compared to the two pure liquids.
D. there are strong dipole-dipole attractions between benzene and n-butanol molecules.

Question #: 18

The liquids pentane and ethylene glycol are not miscible (i.e., they are insoluble in one another) because

A. intermolecular attractions between pentane molecules are much stronger than intermolecular attractions between ethylene glycol molecules
B. they are both liquids, and solutes must be solid
C. intermolecular attractions between pentane and ethylene glycol molecules are weaker than mutual intermolecular attractions between pentane molecules and between ethylene glycol molecules
D. the entropy of a solution of ethylene glycol in pentane would be less than the entropy of pure pentane and pure ethylene glycol
**Question #**: 19

In a **unsaturated** aqueous solution of MgCl$_2$ with solid MgCl$_2$ present,

A. MgCl$_2$ is precipitating more rapidly than solid MgCl$_2$ is dissolving.  
B. the processes of dissolution and precipitation have stopped.  
C. MgCl$_2$ is precipitating at the same rate that solid MgCl$_2$ is dissolving.  
D. solid MgCl$_2$ is dissolving more rapidly than MgCl$_2$ is precipitating.

**Question #**: 20

Water (100.0 g) and solid K$_2$Cr$_2$O$_7$ (30.0 g) are warmed from 30 °C to 50 °C with stirring. Describe the solution process.

A. A saturated solution of K$_2$Cr$_2$O$_7$ results at 50 °C.  
B. About half of the K$_2$Cr$_2$O$_7$ dissolves, but most of it remains as a solid at 50 °C.  
C. No K$_2$Cr$_2$O$_7$ dissolves at 50 °C because ionic solutes are less water soluble at higher temperatures.  
D. An unsaturated solution of K$_2$Cr$_2$O$_7$ results at 50 °C.
Question #: 21

An aqueous solution is saturated in both N\_2 and KBr at 25 °C. If the solution is warmed to 80 °C, which of the following processes is most likely to occur?

A. Some N\_2 bubbles out of solution but no KBr precipitates.
B. No N\_2 bubbles out of solution but some KBr precipitates.
C. Some N\_2 bubbles out of solution and some KBr precipitates.
D. All of the N\_2 bubbles out of solution and all of the KBr precipitates.

Question #: 22

The molality of a solution prepared by dissolving 21 grams of sodium bromide (102.9 g/mol) in 85.0 grams of water is \_1\_ m. Enter your answer with \textbf{two} significant figures. Do \textbf{NOT} include units in your answer.

1. \underline{} \\

Question #: 23

A 10.0 L sample of polluted river water with a density of 1.00 g/mL contains 3500 μg (micrograms) of the insecticide DDT (C\textsubscript{14}H\textsubscript{9}Cl\textsubscript{5}). The concentration of DDT is \_1\_ ppm. Report your answer to \textbf{two} significant figures. Do \textbf{NOT} include units in your answer.

1. \underline{} \\

Question #: 24

A 35.0% by mass solution of sucrose (C\textsubscript{12}H\textsubscript{22}O\textsubscript{11}, 342 g/mol) in water at room temperature has a density of 1.15 g/mL. The concentration of this solution is \_1\_ M. Report your answer to \textbf{three} significant figures. Do \textbf{NOT} include units in your answer.

1. \underline{}}
Question #: 25

What is the molality of a 1.35 M sucrose (342 g/mol) solution with a density of 1.018 g/mL?

A. 1.59 M  
B. 1.18 M  
C. 2.43 M  
D. 2.16 M

Question #: 26

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

\[ \text{Na}_2\text{SO}_4 \quad 1 \]  
\[ \text{MgSO}_4 \quad 2 \]  
\[ \text{KBr} \quad 3 \]

1.  
2.  
3.  

Question #: 27

A solution at 25 °C contains 0.80 mol H₂O and 0.10 mol of nonvolatile glucose (C₆H₁₂O₆). \( P^\circ(\text{H}_2\text{O}) \) is 24 torr at 25 °C.
The vapor pressure of the solution is \( 1 \) torr.
Report your answer with two significant figures. Do NOT include units in your answer.

1.  


Question #: 28

What is the boiling point of a solution of 110. g potassium dichromate (K₂Cr₂O₇, 294 g/mol) in 1.50 × 10² g H₂O?  

\[ K_b(H_2O) = 0.512 \, ^\circ C/m \]

A. 103.8 °C  
B. 100.4 °C  
C. 96.0 °C  
D. 99.3 °C

Question #: 29

An osmotic cell with a semipermeable membrane is set up with pure water in the left chamber and 1.50 M KCl in the right chamber. What happens as the cell reaches equilibrium?

A. The liquid level in the left (H₂O) cell rises.  
B. The liquid level in the right (1.50 M KCl) cell rises.  
C. The levels remain the same.
Question #: 30

Of the aqueous solutions below, solution 1 (A, B, or C) has the lowest boiling point and solution 2 (A, B, or C) has the lowest freezing point.

A. 0.02 \text{ m} \text{ MgBr}_2
B. 0.01 \text{ m} \text{ KI}
C. 0.01 \text{ m} \text{ Li}_3\text{PO}_4

1. ____________
2. ____________
Question #: 1

<table>
<thead>
<tr>
<th>Molecular State</th>
<th>Density</th>
<th>Shape</th>
<th>Volume</th>
<th>Intermolecular Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>solid</td>
<td>high</td>
<td>definite</td>
<td>definite</td>
<td>1 [strong, weak]</td>
</tr>
<tr>
<td>liquid</td>
<td>2 [high, low]</td>
<td>indefinite</td>
<td>3 [definite, indefinite]</td>
<td>moderate</td>
</tr>
</tbody>
</table>
Of the following compounds, 1 has the highest boiling point because it has the strongest 2 [fill in a type of intermolecular force] intermolecular forces in the liquid phase.

1. n-hexane
2. dispersion|dispercion|dispertion|London|

Which figure shows a very strong hydrogen bond?

A.
Question #: 4

Choose the two true statements below about surface tension.

A. Surface tension is the tendency of liquids to maximize their surface area.

✓B. Surface tension results from the higher potential energy of surface molecules compared to interior molecules in a liquid.

✓C. Generally, liquids with high surface tension also have high viscosity.

D. Surface tension is the resistance of a liquid to flow.

Question #: 5
A sample of ethanol (C₂H₅OH) is introduced into a sealed container. **Before** dynamic equilibrium is reached, the rate of condensation is ________ the rate of evaporation of ethanol.

✓A. less than  
B. equal to  
C. greater than  
D. the opposite of

**Question #**: 6

The normal boiling point of toluene (C₇H₈) is 384 K. The boiling point of toluene at 1.55 atm is ___ K.
Enter your answer as a **Kelvin** temperature with **three** significant digits and **without** units. The heat of vaporization, ΔH_{vap}, of toluene is 38.1 kJ/mol.

1. 399|400|401|402|403|404|405|406|407|391|392|393|394|395|396|397|398

**Question #**: 7

Which of the following statements is **true** about the critical point for a substance?

A. Only a gas exists above the critical temperature.  
✓B. Only a supercritical fluid exists above the critical point.  
C. The critical pressure is the pressure above which a liquid is stable.  
D. The critical point is the point at which two phases of a substance are in equilibrium.

**Question #**: 8

Choose the **two true** statements below.

✓A. Melting (fusion) is an endothermic process.  
B. Sublimation is an exothermic process.  
✓C. When a solid is heated to its melting point, the temperature of the solid remains constant while the substance melts.  
D. The heat of fusion of a substance is generally larger than its heat of vaporization.
Question #: 9

Which one of these phase changes is generally the most exothermic?

A. fusion
✓ B. deposition
C. vaporization
D. sublimation

Question #: 10

What is $\Delta H_{\text{system}}$ when 58.5 g of solid benzene, C$_6$H$_6$(s), at 5.53 °C is converted to benzene vapor, C$_6$H$_6$(g), at 80.1 °C?

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</tr>
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A. +24.2 kJ
B. −7.70 kJ
✓ C. +38.0 kJ
D. −52.1 kJ

Question #: 11
Identify the **point** on the phase diagram or the **process** that occurs navigating between the specified points.

Decreasing the temperature at constant pressure from point C to point D.  

Point B.  2

Point G.  3

Choose from the following to fill in each blank: **solid-liquid equilibrium, solid-gas equilibrium, vaporization, condensation, triple point, critical point**

1. condensation|condensation|condensation|
2. triple point
3. solid-gas equilibrium

---

**Question #**: 12

Which of these cubic unit cells has the **greatest** packing efficiency?

✓ A.
Question #: 13

The formula of the ionic compound with the unit cell below is $\text{Pb}_1 \text{Zr}_1 \text{O}_3$. List the formula in the order $\text{Pb} \# \text{Zr} \# \text{O} \#$, with the lowest whole-number coefficient for each element (even if it is 1) and a space between each element.
Question #: 14

Barium metal crystallizes in a body-centered cubic lattice, as shown below, with an edge length of 507 pm. The density of barium is \( \text{1 g/cm}^3 \). Report your answer with two significant digits. Do NOT include units in your answer.

1. 3.5|3.4|3.6|

Question #: 15

Iodine, \( \text{I}_2 \), has a melting point of 114 °C, whereas methanol (\( \text{CH}_3\text{OH} \)) has a melting point of –98 °C. Why is this true?
A. Dispersion forces in iodine are stronger than dipole-dipole, hydrogen bonding, and dispersion forces in methanol.
B. Dispersion forces are always stronger than hydrogen bonding forces.
C. Iodine is a network covalent solid.
D. Ionic solids are higher melting than molecular solids.

Question #: 16

Provide a term to describe the electrical behavior of each of the materials on the band diagram below.
Figure 1 illustrates a(n) __1__.  
Figure 2 illustrates a(n) __2__.  
Figure 3 illustrates a(n) __3__.

1. metal/metall/medal|  
2. semiconductor/semi conductor/semiconductor|  
3. insulator/insulater/insulation|
Benzene \((\text{C}_6\text{H}_6)\) and n-butanol \((\text{C}_4\text{H}_9\text{OH})\) are miscible with one another in all proportions because

A. they form strong hydrogen bonds with one another.
B. there is a large decrease in potential energy for the mixed liquids compared to the two pure liquids.
✓ C. there is a large increase in entropy for the mixed liquids compared to the two pure liquids.
D. there are strong dipole-dipole attractions between benzene and \(n\)-butanol molecules.

**Question #**: 18

The liquids pentane and ethylene glycol are **not** miscible (i.e., they are insoluble in one another) because __________.

A. intermolecular attractions between pentane molecules are much stronger than intermolecular attractions between ethylene glycol molecules
B. they are both liquids, and solutes must be solid
✓ C. intermolecular attractions between pentane and ethylene glycol molecules are weaker than mutual intermolecular attractions between pentane molecules and between ethylene glycol molecules
D. the entropy of a solution of ethylene glycol in pentane would be less than the entropy of pure pentane and pure ethylene glycol
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In a **unsaturated** aqueous solution of MgCl₂ with solid MgCl₂ present,

A. MgCl₂ is precipitating more rapidly than solid MgCl₂ is dissolving.
B. the processes of dissolution and precipitation have stopped.
C. MgCl₂ is precipitating at the same rate that solid MgCl₂ is dissolving.
✓D. solid MgCl₂ is dissolving more rapidly than MgCl₂ is precipitating.

Question #: 20

Water (100.0 g) and solid K₂Cr₂O₇ (30.0 g) are warmed from 30 °C to 50 °C with stirring. Describe the solution process.

✓A. A saturated solution of K₂Cr₂O₇ results at 50 °C.
B. About half of the K₂Cr₂O₇ dissolves, but most of it remains as a solid at 50 °C.
C. No K₂Cr₂O₇ dissolves at 50 °C because ionic solutes are less water soluble at higher temperatures.
D. An unsaturated solution of K₂Cr₂O₇ results at 50 °C.
Question #: 21

An aqueous solution is saturated in both $N_2$ and KBr at 25 ºC. If the solution is warmed to 80 ºC, which of the following processes is most likely to occur?

✓A. Some $N_2$ bubbles out of solution but no KBr precipitates.
B. No $N_2$ bubbles out of solution but some KBr precipitates.
C. Some $N_2$ bubbles out of solution and some KBr precipitates.
D. All of the $N_2$ bubbles out of solution and all of the KBr precipitates.

Question #: 22

The molality of a solution prepared by dissolving 21 grams of sodium bromide (102.9 g/mol) in 85.0 grams of water is __1__ $m$.
Enter your answer with two significant figures. Do NOT include units in your answer.

1. 2.4|2.4E0|

Question #: 23

A 10.0 L sample of polluted river water with a density of 1.00 g/mL contains 3500 μg (micrograms) of the insecticide DDT (C$_{14}$H$_9$Cl$_5$). The concentration of DDT is __1__ ppm.
Report your answer to two significant figures. Do NOT include units in your answer.

1. 0.35|0.35|0.36|0.36|0.34|0.34|

Question #: 24

A 35.0% by mass solution of sucrose (C$_{12}$H$_{22}$O$_{11}$, 342 g/mol) in water at room temperature has a density of 1.15 g/mL. The concentration of this solution is __1__ M.
Report your answer to three significant figures. Do NOT include units in your answer.

1. 1.18|1.19|1.20|1.16|1.17|

Question #: 25
What is the **molality** of a 1.35 M sucrose (342 g/mol) solution with a density of 1.018 g/mL?

A. 1.59 M  
B. 1.18 M  
✓C. 2.43 M  
D. 2.16 M

---

**Question #**: 26

For each of the following solutes, enter the expected van't Hoff factor as a whole number (integer).

\[
\begin{align*}
\text{Na}_2\text{SO}_4 & \quad 1 \\
\text{MgSO}_4 & \quad 2 \\
\text{KBr} & \quad 3 \\
\end{align*}
\]

1. 3  
2. 2  
3. 2

---

**Question #**: 27

A solution at 25 °C contains 0.80 mol H₂O and 0.10 mol of nonvolatile glucose (C₆H₁₂O₆).  
\(P^o(\text{H}_2\text{O})\) is 24 torr at 25 °C.  
The vapor pressure of the solution is \_1\_ torr.  
Report your answer with **two** significant figures. Do **NOT** include units in your answer.

1. 21|21.3|

---

**Question #**: 28

What is the boiling point of a solution of 110. g potassium dichromate (K₂Cr₂O₇, 294 g/mol) in \(1.50 \times 10^2\) g H₂O?  
\(K_b (\text{H}_2\text{O}) = 0.512 \text{ °C/m}\)
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Of the aqueous solutions below, solution 1 (A, B, or C) has the lowest boiling point and solution 2 (A, B, or C) has the lowest freezing point.

A. 0.02 \text{ m} \text{MgBr}_2
B. 0.01 \text{ m} \text{KI}
C. 0.01 \text{ m} \text{Li}_3\text{PO}_4
1. B|B.|b|b.|