1. Which of the following orders of electronegativity is incorrect?
   (a) $\text{Si} < \text{P} < \text{N}$
   (b) $\text{N} < \text{P} < \text{S}$
   (c) $\text{I} < \text{Cl} < \text{F}$
   (d) $\text{Se} < \text{S} < \text{O}$
   (e) $\text{Si} < \text{N} < \text{O}$

2. How many valence electrons are shown in the Lewis structure of $\text{NO}_3^-$?
   (a) 11  (b) 15  (c) 22  (d) 23  (e) 24

3. Which of the following molecules is nonpolar?
   (a) $\text{CH}_3\text{Cl}$  (b) $\text{CCl}_4$  (c) $\text{CO}$  (d) $\text{H}_2\text{O}$  (e) $\text{HF}$

4. Which of the following intermolecular forces is the strongest?
   (a) dipole-dipole forces
   (b) hydrogen bonding
   (c) dispersion forces
   (d) London forces
   (e) ion-dipole forces

5. Drawing (1) shows the equilibrium vapor pressure of a pure liquid. Which drawing (2) - (5) represents the equilibrium vapor pressure when a nonvolatile solute is dissolved in the liquid?
   (a) Drawing (3)
   (b) Drawing (2)
   (c) Drawing (5)
   (d) Drawing (4)
6. The following pictures represent the equilibrium state for four different reactions of the type $A_2 + X_2 \leftrightarrow 2 AX$ ($X = B, C, D, E$). A atoms are open circles. X atoms are closed circles. Which reaction has the smallest equilibrium constant?

(a) $A_2 + E_2 \leftrightarrow 2 AE$
(b) $A_2 + D_2 \leftrightarrow 2 AD$
(c) $A_2 + C_2 \leftrightarrow 2 AC$
(d) $A_2 + B_2 \leftrightarrow 2 AB$

7. The maximum allowable limit of copper in 1 L of water as set by the EPA is 1.3 mg. What is the level expressed in parts per million (ppm)?

(a) $1.3 \times 10^{-6}$
(b) 1.3
(c) $1.3 \times 10^{-3}$
(d) 13
(e) 0.13

8. Which of the following solutions has the lowest boiling point?

(a) 0.1 m urea
(b) 0.06 m HCl in water
(c) 0.05 m CaCl$_2$ in water
(d) 0.04 (NH$_4$)$_3$PO$_4$ in water
(e) 0.07 m NaCl in water

<table>
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<th>Molality of particles</th>
<th>0.10</th>
<th>0.12</th>
<th>0.15</th>
<th>0.16</th>
<th>0.14</th>
</tr>
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<tbody>
<tr>
<td>(a) 0.1 m urea</td>
<td>lowest b.p. is sol’n with the smallest molality of particles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. $K_P$ for the reaction $H_2(g) + I_2(g) \leftrightarrow 2 HI(g)$ is 54.3 at 698°C. What is the value of $K_C$ at this temperature?

(a) $1.80 \times 10^{-2}$
(b) $2.30 \times 10^{-4}$
(c) 85.6
(d) 54.3
(e) $4.33 \times 10^3$
10. Which direction will the following reaction (in a 5.0 L flask) proceed if the pressure of CO$_2$(g) is 1.0 atm?

\[
\text{CaCO}_3(s) \leftrightarrow \text{CaO}(s) + \text{CO}_2(g)
\]

\[K_p = 1.9 \times 10^{-23}\]

(a) to the right because \( Q < K_p \)

(b) to the left because \( Q < K_p \)

(c) to the right because \( Q > K_p \)

(d) to the left because \( Q > K_p \)

(e) The reaction is at equilibrium.

11. For the system NH$_4$HS(s) ↔ NH$_3$(g) + H$_2$S(g), the equilibrium constant expression is

(a) \([\text{NH}_3]\) [H$_2$S]

(b) \([\text{NH}_3]\) [H$_2$S] / [NH$_4$HS]

(c) \(1 / [\text{NH}_3] [\text{H}_2\text{S}]\)

(d) \([\text{NH}_4\text{HS}] / [\text{NH}_3] [\text{H}_2\text{S}]\)

12. The equilibrium system PCl$_5$(g) ↔ PCl$_3$(g) + Cl$_2$(g) is disturbed by adding chlorine. When equilibrium is reestablished, what can be predicted about the new concentration compared to the original equilibrium concentration?

(a) [PCl$_5$] is larger, [PCl$_3$] smaller, [Cl$_2$] larger

(b) [PCl$_5$] is larger, [PCl$_3$] larger, [Cl$_2$] larger

(c) [PCl$_5$] is larger, [PCl$_3$] smaller, [Cl$_2$] smaller

(d) [PCl$_5$] is larger, [PCl$_3$] larger, [Cl$_2$] smaller

(e) [PCl$_5$] is smaller, [PCl$_3$] larger, [Cl$_2$] larger

13. Consider the reaction CO(g) + H$_2$O(g) ↔ CO$_2$(g) + H$_2$(g) \( \Delta H^\circ = -41 \text{ kJ} \)

All of the following changes would shift the equilibrium to the right except one. Which one would not cause the equilibrium to shift to the right?

(a) Remove some CO$_2$.

(b) Increase the partial pressure of H$_2$O.

(c) Add some CO.

(d) Decrease the temperature.

(e) Decrease the container volume.
14. (a) What is the shape (molecular geometry) of CS₂? (Circle one and show work.) 4 pts
tetrahedral  linear  bent  \( \ddot{S} = C = \ddot{S} \)
(b) Is BH₃ polar or nonpolar? (Show work)
Nonpolar

(c) List all intermolecular forces present in a sample of CS₂? 4 pts
dispersion

15. Consider the following endothermic reaction:
\[ \text{PCl}_5(g) \leftrightarrow \text{PCl}_3(g) + \text{Cl}_2(g) \]
(a) At a certain temperature, the equilibrium mixture contains 1.3 atm PCl₅, 0.12 atm PCl₃ and 7.25 atm Cl₂. What is the equilibrium constant, \( K_P \), for this reaction? 4 pts
\[ K_P = \frac{(P_{\text{PCl}_3})(P_{\text{Cl}_2})}{(P_{\text{PCl}_5})} = \frac{(0.12)(7.25)}{(1.3)} \]
\[ K_P = 0.67 \]
(b) If 1.25 mole of PCl₃(g) and 1.25 mole of Cl₂(g) are placed in a 5.00-L container, the above equilibrium is reached. What is the equilibrium concentration of PCl₃ and Cl₂? (\( K_C = 10.0 \) at the reaction temperature for the above reaction) 5 pts
\[ \text{Inita}l \quad \text{PCl}_5(g) \quad \leftrightarrow \quad \text{PCl}_3(g) \quad \text{+} \quad \text{Cl}_2(g) \]
\[ \text{Change} \quad +x \quad -x \quad -x \]
\[ \text{Equilibrium} \quad x \quad 0.25 - x \quad 0.25 - x \]
\[ 10.0 = \frac{(0.25 - x)^2}{x} = \frac{0.0625 - 0.50x + x^2}{x} \]
\[ x^2 - 10.500x + 0.0625 = 0 \]
\[ x = 10.494, \ 0.006 \]
\[ P_{\text{PCl}_3} = P_{\text{Cl}_2} = 0.25 - (0.006) = 0.24 \text{ M} \]
(c) Will a decrease in temperature favor the decomposition of PCl₅? 4 pts
No
(d) Will an increase in volume favor the decomposition of PCl₅? 4 pts
Yes
16. Lysine, one of the amino acid building blocks found in proteins, contains 49.29% C, 9.65% H, 19.16% N, and 21.89% O by elemental analysis. A solution prepared by dissolving 30.0 mg of lysine in 1.200 g of the organic solvent biphenyl, gives a freezing-point depression of 1.37°C. What is molecular formula of lysine? (Lysine does not dissociate.) (K_f for biphenyl is 8.00°C/m)

C: \((49.29 \text{ g})(1 \text{ mol/12.011 g}) = 4.104 \text{ mol} \Rightarrow 3\)
H: \((9.65 \text{ g})(1 \text{ mol/1.0079 g}) = 9.5744 \text{ mol} \Rightarrow 7\)
N: \((19.16 \text{ g})(1 \text{ mol/14.0067 g}) = 1.36792 \text{ mol} \Rightarrow 1\)
O: \((21.89 \text{ g})(1 \text{ mol/15.9994 g}) = 1.36818 \text{ mol} \Rightarrow 1\)

Empirical formula: \(\text{C}_3\text{H}_7\text{NO}\)  Molar mass = 73 g/mol

\[\Delta T_f = K_fm\]
\[1.37^\circ C = (8.00^\circ C/m) m\]
\[m = 0.17125 \text{ mol/kg}\]

\[\frac{(1.200 \times 10^{-3} \text{ kg})(0.17125 \text{ mol/kg})}{2.055 \times 10^{-4} \text{ mol}} = 2.055 \times 10^{-4} \text{ mol}\]

Molar mass = \(\frac{(30.0 \times 10^{-3} \text{ g})}{(2.055 \times 10^{-4} \text{ mol})} = 146 \text{ g/mol}\)

\[\frac{(146 \text{ g/mol})}{(73 \text{ g/mol})} = 2\]

**Molecular formula = \(\text{C}_6\text{H}_{14}\text{N}_2\text{O}_2\)**