1. Which order is correct for increasing polarity (least polar first)?

\[
\begin{array}{c}
S—Cl \\
Si—Cl \\
P—Cl \\
Si—Si
\end{array}
\]

A  B  C  D

(a)  A < B < C < D  (d)  D < C < B < A
(b)  C < D < A < B  (e)  D < A < C < B
(c)  C < A < D < B

2. How many valence electrons are shown in the Lewis structure of \( \text{NO}_2^+ \)?

(a) 11  (b) 15  (c) 16  (d) 17  (e) 18

3. Which of the following molecules contains polar bonds but is nonpolar?

(a) \( \text{CH}_2\text{Cl}_2 \) (C is central atom)  (d) \( \text{NH}_3 \)
(b) \( \text{F}_2 \)  (e) \( \text{CCl}_4 \)
(c) \( \text{H}_2\text{O} \)

4. When water boils, what primary forces are overcome?

(a) An H—O bond is broken.
(b) Both of the H—O bonds are broken.
(c) Only the dispersion forces are overcome.
(d) Hydrogen bonding forces are overcome.

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 (2)
(b) Drawing (3)
(c) Drawing (4)
(d) Drawing (5)
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 largest equilibrium constant?

(a) $A_2 + B_2 \leftrightarrow 2 AB$

(b) $A_2 + C_2 \leftrightarrow 2 AC$

(c) $A_2 + D_2 \leftrightarrow 2 AD$

(d) $A_2 + E_2 \leftrightarrow 2 AE$

7. Express a concentration of 0.0010% NaCl by mass as ppm.

(a) $1.0 \times 10^{-2}$

(b) 0.10

(c) 1.0

(d) 10

(e) 100

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

(a) 1.0 m glucose in water

(b) 1.0 m NaCl in water

(c) 1.0 m NaBr in water

(d) 1.0 CaCl$_2$ in water

(e) water

Molality of particles

<table>
<thead>
<tr>
<th>Solution</th>
<th>Molality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 m glucose</td>
<td>1.0</td>
</tr>
<tr>
<td>1.0 m NaCl</td>
<td>2.0</td>
</tr>
<tr>
<td>1.0 m NaBr</td>
<td>2.0</td>
</tr>
<tr>
<td>1.0 CaCl$_2$</td>
<td>3.0</td>
</tr>
<tr>
<td>Water</td>
<td>0.0</td>
</tr>
</tbody>
</table>

lowest b.p. is sol’n with the smallest molality of particles

9. For the gaseous system,

$$2 \text{H}_2\text{S}(g) + 3 \text{O}_2(g) \leftrightarrow 2 \text{H}_2\text{O}(g) + 2 \text{SO}_2(g)$$

how is $K_P$ related to $K_C$ at a given temperature?

(a) less than

$$K_P = K_C (RT)^\Delta n$$

$\Delta n = 4-5 = -1$

so $K_P < K_C$

(b) equal to

(c) greater than

(d) unrelated to
10. A mixture is prepared with \([\text{CO}] = 0.035 \text{ M}, [\text{Cl}_2] = 0.015 \text{ M} \) and \([\text{COCl}_2] = 0.95 \text{ M}\). It is known that \(K_C\) for the equilibrium \(\text{CO(g)} + \text{Cl}_2(g) \rightleftharpoons \text{COCl}_2(g)\) is \(1.2 \times 10^3\) at 400°C. Predict what will happen.

(a) The reaction is at equilibrium so no net reaction occurs.  
\[ Q = \frac{0.95}{(0.035)(0.015)} \]
(b) The reaction occurs in the forward direction.  
\[ Q = 1.8 \times 10^3 \]
(c) The reaction occurs in the reverse direction.  
(d) It is impossible to predict without more information.

11. For the system \(\text{CaO(s)} + \text{CO}_2(g) \rightleftharpoons \text{CaCO}_3(s)\), the equilibrium constant expression is

(a) \([\text{CaCO}_3] / [\text{CaO}] [\text{CO}_2]\)
(b) \(1 / [\text{CaO}] [\text{CO}_2]\)
(c) \(1 / [\text{CO}_2]\)
(d) \([\text{CaO}] [\text{CO}_2] / [\text{CaCO}_3]\)

12. An equilibrium mixture of \(\text{NO(g)}\), \(\text{O}_2(g)\) and \(\text{NO}_2(g)\) is allowed to expand from 1.0 L to 2.0 L at constant temperature. \(2 \text{ NO(g)} + \text{O}_2(g) \rightleftharpoons 2 \text{ NO}_2(g)\)
Which of the following statements is correct?

(a) Concentration of all three gases are unchanged.
(b) The value of \(K_P\) would decrease.
(c) The number of moles of \(\text{NO}_2\) would increase.
(d) The number of moles of \(\text{O}_2\) would increase.
(e) The number of moles of all three gases are unchanged.

If volume increases then pressure decreases so the equilibrium will shift in the direction of larger number of moles of gas (left). \(K\) stays same.

13. Consider the reaction \(2 \text{ SO}_3(g) \rightleftharpoons 2 \text{ SO}_2(g) + \text{O}_2(g)\) \(\Delta H° = +198 \text{ kJ}\)

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

(a) Add some \(\text{SO}_2\).
(b) Remove some \(\text{SO}_3\).
(c) Decrease the temperature.
(d) Increase the container volume.

Adding product will cause shift to left. Removing reactant will cause shift to left. Decreasing T will cause shift to left (endothermic). Increasing V will decrease P causing shift toward larger number of moles of gas (right).

END OF SCANTRON PORTION OF EXAM
14. (a) What is the shape (molecular geometry) of SO$_2$? (Circle one and show work.)  
- tetrahedral  
- linear  
- bent  
- $\ddot{O} - \ddot{S} = \ddot{O}$  
4 pts

(b) Is PCl$_3$ polar or nonpolar? (Show work)  
- $\text{Cl} - \bar{P} - \text{Cl}$  
- Polar  
- I  
- Cl  
4 pts

(c) List all intermolecular forces present in a sample of SO$_2$?  
- dipole-dipole  
- dispersion  
4 pts

15. Consider the following endothermic reaction:  
\[ \text{NH}_4\text{HS}(s) \leftrightarrow \text{NH}_3(g) + \text{H}_2\text{S}(g) \]

(a) $\text{NH}_4\text{HS}(s)$ is placed in a vessel and decomposes at $22^\circ$C. After equilibrium is reached, 0.26 atm of both NH$_3$ and H$_2$S are present along with solid NH$_4$HS.  
What is the equilibrium constant, $K_P$, for this reaction?  
4 pts

\[ K_P = (0.26)(0.26) = 0.0676 \]

\[ \boxed{K_P = 0.068} \]

(b) Suppose that 0.0935 atm of pure NH$_3$(g) and 0.0935 atm of pure H$_2$S(g) are placed in a 5.00 L flask at 50°C ($K_P @ 50^\circ$C = 0.52). What are the partial pressures of NH$_3$ and H$_2$S at equilibrium?  
5 pts

\[
\begin{array}{ccccc}
\text{NH}_4\text{HS}(s) & \leftrightarrow & \text{NH}_3(g) & + & \text{H}_2\text{S}(g) \\
\text{Initial} & \text{----} & 0.0935 & 0.0935 \\
\text{Change} & \text{----} & -x & -x \\
\text{Equilibrium} & \text{----} & 0.0935 - x & 0.0935 - x \\
\end{array}
\]

\[ 0.52 = (0.0935 - x)^2 = 0.00874225 - 0.187x + x^2 \]

\[ x^2 - 0.187x - 0.51125775 = 0 \]

\[ x = 0.8146, -0.6276 \]

\[ P_{\text{NH}_3} = P_{\text{H}_2\text{S}} = 0.0935 - (-0.6276) = 0.721 \text{ atm} \]

(c) Will an increase in temperature favor the decomposition of NH$_4$HS?  
- Yes  
4 pts

(d) Will a decrease in volume favor the decomposition of NH$_4$HS?  
- No  
4 pts
BONUS QUESTION

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)

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

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

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

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

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