1)(20 pts.) Multiple Choice – Circle the correct answer. Correct answer is underlined.

1) In which substance would the induced dipole-induced dipole forces be the weakest?
   a) He   b) Ne   c) Ar   d) Kr   e) Xe

2) In which substance would the induced dipole-induced dipole forces be the weakest?
   a) H₂   b) F₂   c) Cl₂   d) Br₂   e) I₂

3) Which substance would exhibit dipole-dipole intermolecular forces?
   a) H₂   b) CF₄   c) CO₂   d) Br₂   e) NH₃

4) The boiling points of the noble gases increase as you go down column 8. What type of intermolecular force can account for this fact?
   a) ion-ion   b) dipole-dipole   c) ion-dipole   d) H-bonding   e) induced dipole-induced dipole

5) Calculate the molarity of a solution of 40.0 g glucose (C₆H₁₂O₆) in enough water to make 40.0 ml of solution.
   a) 0.10 M   b) 0.09 M   c) 0.22 M   d) 5.56 M   e) None of the above.

6) Which of the following pairs is least likely to mix.
   a) Methanol (H₃COH) & Water (H₂O)
   b) Hexane (C₆H₁₄) & Octane (C₈H₁₈)
   c) Potassium Chloride (KCl) & Carbon tetrachloride (CCl₄)
   d) Acetic acid (CH₃COOH) & Water (H₂O)
   e) Iodine (I₂) & Benzene (C₆H₆)
2)(35 pts.) For the reaction that produces metallic iron from iron ore shown below:

\[ 2 \text{Fe}_2\text{O}_3(s) + 3 \text{C}(s) \rightarrow 4 \text{Fe}(s) + 3 \text{CO}_2(g) \]

<table>
<thead>
<tr>
<th></th>
<th>( \Delta H^\circ ) (kJ/mole)</th>
<th>( S^\circ ) (J/mole-K)</th>
<th>( \Delta G^\circ ) (kJ/mole)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Fe}_2\text{O}_3(s) )</td>
<td>-822</td>
<td>90</td>
<td>?</td>
</tr>
<tr>
<td>( \text{Fe}(s) )</td>
<td>0</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>( \text{C}(s) )</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>( \text{CO}_2(g) )</td>
<td>-394</td>
<td>214</td>
<td>-394</td>
</tr>
</tbody>
</table>

a) Calculate the value of \( \Delta S^\circ \) for the reaction.

\[ \Delta S^\circ_{\text{rxn}} = -\Sigma S^\circ_{\text{reactants}} + \Sigma S^\circ_{\text{products}} \]
\[ \Delta S^\circ_{\text{rxn}} = -(2\text{mole} \times 90\text{J/mole-K} + 3\text{mole} \times 5\text{J/mole-K}) + (4\text{mole} \times 27\text{J/mole-K} + 3\text{mole} \times 214\text{J/mole-K}) \]
\[ \Delta S^\circ_{\text{rxn}} = 555 \text{ J/K} \]

b) Disorder is increasing as \( \Delta S^\circ_{\text{rxn}} > 0 \)

5 moles of reactants \( \rightarrow \) 7 moles of products
solids \( \rightarrow \) gases

More moles, more mobility leads to greater disorder and lack of information about the system.

c) \( \Delta H^\circ_{\text{rxn}} = -\Sigma \Delta H^\circ_{\text{reactants}} + \Sigma \Delta H^\circ_{\text{products}} \)
\[ \Delta H^\circ_{\text{rxn}} = -(2\text{mole} \times -822\text{kJ/mole} + 3\text{mole} \times 0\text{kJ/mole}) + (4\text{mole} \times 0\text{kJ/mole} + 3\text{mole} \times -394\text{kJ/mole}) \]
\[ \Delta H^\circ_{\text{rxn}} = 462 \text{ kJ} \]
\[ \Delta G^\circ_{\text{rxn}} = \Delta H^\circ_{\text{rxn}} - T\Delta S^\circ_{\text{rxn}} = 462 \text{ kJ} - 298K \times 555 \text{ J/K} \times (1\text{kJ}/1000 \text{ J}) \]
\[ \Delta G^\circ_{\text{rxn}} = +297 \text{ kJ} \]

d) \( \Delta G^\circ_{\text{rxn}} > 0 \)
Reaction is endergonic and non-spontaneous at 298 K.
The reaction needs the energy of the furnace in order to go uphill in energy to products. Since \( \Delta H^\circ_{\text{rxn}} > 0 \) and \( \Delta S^\circ_{\text{rxn}} > 0 \) this reaction will be spontaneous at higher temperatures. The furnace provides the high temperature environment that makes the reaction spontaneous.

e) \( \Delta G^\circ_{\text{rxn}} = -\Sigma \Delta G^\circ_{\text{reactants}} + \Sigma \Delta G^\circ_{\text{products}} \)
\[ +297 \text{ kJ} = -(2\text{mole} \times X \text{kJ/mole} + 3\text{mole} \times 0\text{kJ/mole}) + (4\text{mole} \times 0\text{kJ/mole} + 3\text{mole} \times -394\text{kJ/mole}) \]
\[ +297 \text{ kJ} = -2X \text{kJ} -1182 \text{ kJ} \]
\[ X = \frac{(297 \text{ kJ} + 1182 \text{ kJ})}{-2 \text{ mol}} = -739.5 \text{ kJ/mol} \]
3)(24 pts.) Would you expect each of the following reactions to be spontaneous at low temperatures, high temperatures, all temperatures or not at all? What is the change in the entropy of the system? Explain for full credit.

a) \(2 \text{NH}_3(g) \rightarrow \text{N}_2(g) + 3 \text{H}_2(g)\) \(\Delta H = +92\) kJ
Since 2 moles of reactants \(\rightarrow\) 4 moles of products \(\Delta S > 0\)
\[\Delta G = \Delta H - T\Delta S\]
\[+ - (+) (+)\]
\[+ - (+) (+)\]
\(\Delta G < 0\) at high temperatures when \(T\Delta S\) is bigger than \(\Delta H\)

b) \(\text{PCl}_3(g) + \text{Cl}_2(g) \rightarrow \text{PCl}_5(g)\) \(\Delta H = -88\) kJ
Since 2 moles of reactants \(\rightarrow\) 1 moles of products \(\Delta S < 0\)
\[\Delta G = \Delta H - T\Delta S\]
\[- - (+) (-)\]
\[- - (+) (-)\]
\(\Delta G < 0\) at low temperatures when \(T\Delta S\) is smaller than \(\Delta H\)

c) \(2 \text{N}_2\text{O}(g) \rightarrow 2 \text{N}_2(g) + \text{O}_2(g)\) \(\Delta H = -164\) kJ
Since 2 moles of reactants \(\rightarrow\) 3 moles of products \(\Delta S > 0\)
\[\Delta G = \Delta H - T\Delta S\]
\[- - (+) (+)\]
\[- - (+) (+)\]
\(\Delta G < 0\) at all temperatures
4)(23 pts.) A stock solution has a concentration of 0.015 M.
a) How many moles of solute are in 50 ml of your stock solution?
b) If a 1:5 dilution by volume solution was made what would the concentration of the
dilute solution be? 
c) How would you make 20 ml of 0.0025 M solution from the stock solution and
deionized water?
d) If a series of three 1:10 by volume dilutions were made of the stock solution how
many moles of solute would be in 75 ml of the final solution?

a) 0.015 M or moles/L * 50 ml * (1 L/1000 ml) = 7.5x10^{-4} moles of solute

b) 0.015 M \rightarrow 0.003 M after a 1:5 by volume dilution
because \(5 \cdot V_{\text{old}} = V_{\text{new}}\)
\[V_{\text{old}}M_{\text{old}} = V_{\text{new}}M_{\text{new}}\]
\[V_{\text{old}}M_{\text{old}} = 5 \cdot V_{\text{old}} \cdot M_{\text{new}}\]
\[M_{\text{new}} = V_{\text{old}}M_{\text{old}}/5 \cdot V_{\text{old}} = M_{\text{old}}/5 = 0.003 M\]

c) 
\[V_{\text{old}}M_{\text{old}} = V_{\text{new}}M_{\text{new}}\]
\[M_{\text{old}} = 0.015 \text{ M}\]
\[M_{\text{new}} = 0.0025 \text{ M}\]
\[V_{\text{new}} = 0.02 \text{ L}\]
\[V_{\text{old}} = 0.02 \text{ L} \cdot 0.0025 \text{ M} / 0.015 \text{ M} = 0.0033 \text{ L}\]

\[V_{\text{water}} = V_{\text{new}} - V_{\text{old}} = 0.02 \text{ L} - 0.0033 \text{ L} = 0.0167 \text{ L} \cdot (1000 \text{ ml} / 1 \text{ L}) = 16.7 \text{ ml}\]
You need 3.3 ml of the 0.015 M stock solution and 16.7 ml of deionized water to
make 20 ml of a 0.0025 M solution.

d) three serial 1:10 dilutions by volume are the same as \((1:10)^3 = 1:1000\) dilution by volume. The concentration will decrease by a factor of 0.001
\[M_{\text{new}} = 1.5 \times 10^{-5} \text{ M}\]
\[0.075 \text{ L} \cdot 1.5 \times 10^{-5} \text{ M} = 1.13 \times 10^{-6} \text{ moles}\]