Geology 627, Hydrogeology
Review questions for final exam 2004

Multiple choice and fill in the blank. There may be more than one correct choice for each question.

1. Which hydrogeologic quantities are represented by the $W$ in the governing equation

$$\frac{\partial}{\partial x} \left( K_{xx} \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left( K_{yy} \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left( K_{zz} \frac{\partial h}{\partial z} \right) - W = S \frac{\partial h}{\partial t}$$

a) Leakance
b) Water released from storage
c) Recharge
d) Wells

e) Wells

2. The mass action equilibrium relation for the redox half-reaction

$$\frac{1}{2} NO_3^- + H^+ + e^- \Leftrightarrow \frac{1}{2} NO_2^- + \frac{1}{2} H_2O$$

can be written as

a) $10^{-pe^0} = \frac{[NO_3^-]^{1/2} 10^{-pH} 10^{-pe}}{[NO_2^-]^{1/2}}$

b) $10^{-pe^0} = \frac{[NO_2^-]^{1/2}}{[NO_3^-]^{1/2} 10^{-pH} 10^{-pe}}$

c) $pe = pe^0 - \log \frac{[NO_2^-]}{[NO_3^-]}$

d) $pe = pe^0 - \frac{1}{2} \log \frac{[NO_2^-]}{[NO_3^-]} - pH$

e) $pe = pe^0 - \frac{1}{2} \log \frac{[NO_2^-]}{[NO_3^-]} + pH$

3. The fact that groundwater in some parts of Florida system is supersaturated with respect to the mineral calcite can be explained as the result of

a) cation exchange reactions
b) a common ion effect
c) seawater intrusion
d) fast dissolution of calcite coupled to slow precipitation of dolomite
e) disequilibrium among redox reactions
4. Processes occurring at the pore scale that lead to dispersion during solute transport in groundwater include
   a) molecular diffusion
   b) turbulent mixing
   c) higher local velocities in smaller pores
   d) higher local velocities at the centers of pores than near the pore walls

5. Which of the following changes to the conceptual model of a groundwater flow system would require that the leakance parameter, VCONT, in MODFLOW be increased
   a) An increase in areal recharge
   b) An increase in vertical hydraulic conductivity of a confining unit
   c) An increase in thickness of a confining unit
   d) An increase in heads in a confined aquifer

6. The output from a steady-state MODFLOW simulation indicates that the error in the volumetric budget is 10%. When you ran the model in Groundwater Vistas, you got the message that the simulation had failed to converge after 100 iterations. Which of the following strategies could you use in order to improve the simulation result for the aquifer system represented by the original model run?
   a) Increase the number of iterations to 150 while keeping the head change criterion at its original value.
   b) Decrease the head change criterion while keeping the maximum number of iterations equal to 100.
   c) Modify the transmissivity of one of the model layers.
   d) Use the final heads from the first simulation as the starting heads for a second simulation.

7. Which of the following reactions is considered homogeneous?
   a) Acid dissociation
   b) Complexation
   c) Sorption
   d) Mineral precipitation

8. Match each of the parameters in the column on the left with the process in column on the right to which it is most closely related.

   \[ \text{E} \quad \text{CEC} \quad \text{A. molecular diffusion} \]
   \[ \text{C} \quad \sigma_L \quad \text{B. mineral dissolution} \]
   \[ \text{F} \quad \tau_{1/2} \quad \text{C. longitudinal dispersion} \]
   \[ \text{I} \quad \text{pe} \quad \text{D. advection} \]
   \[ \text{A.} \quad \text{molecular diffusion} \]
   \[ \text{B.} \quad \text{mineral dissolution} \]
   \[ \text{C.} \quad \text{longitudinal dispersion} \]
   \[ \text{D.} \quad \text{advection} \]
   \[ \text{E.} \quad \text{cation exchange} \]
   \[ \text{F.} \quad \text{radioactive decay} \]
   \[ \text{G.} \quad \text{isotope fractionation} \]
   \[ \text{H.} \quad \text{dedolomitization} \]
   \[ \text{I.} \quad \text{oxidation-reduction} \]
   \[ \text{J.} \quad \text{gas-water partitioning} \]
Problems

1. The diagram below illustrates hydrogeologic conditions in a closed basin in Texas. You are asked to develop a MODFLOW model for this basin.

![Diagram of a closed basin in Texas with地下水条件说明。](image)

**Figure 23.** No water flows out of the closed Salt Basin. Recharge to the basin fill is from runoff in the surrounding mountains that enters the basin near its margins. Ground water moves downward and laterally through the basin fill and discharges by evapotranspiration at playas near the center of the basin.

a) How may layers would you use in the model to represent the alluvium? Explain your reasoning. There are a number of possible correct answers depending on how well you want to represent the geometry of the basin.

b) How would transmissivity vary within the layers you defined in part a)? Explain your reasoning. Correct answer depends on the answer to part A. If you use only one layer, then T will be high in the center of the basin, low at the margins.

c) How would you account for the bedrock in your model? Explain your reasoning. Again there are several possible correct answers, but the simplest would be to represent the bedrock as a no-flow boundary.

d) What are sources of groundwater to this basin? How could you represent these in your model? (Be sure to discuss the spatial distribution of sources.) Recharge concentrated at the margins of the basin, represented by high recharge rates around the edges of the uppermost model layer.
e) What are the sinks for groundwater in this basin? How could you represent these in your model? (Be sure to discuss the spatial distribution of sinks.) **ET at the center of the basin, could be represented using the ET package or by wells pumping at a low rate.**

2. You recently purchased a cabin in South Carolina that you plan to use for summer vacations and eventually as a retirement home. The water supply comes from a well completed in coastal plain sediments. A recent chemical analysis provided to you by the previous owner shows that the water has the following composition:

<table>
<thead>
<tr>
<th>Ion</th>
<th>mg/L</th>
<th>mmol/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca(^{2+})</td>
<td>20.0</td>
<td>0.499</td>
</tr>
<tr>
<td>Mg(^{2+})</td>
<td>1.7</td>
<td>0.070</td>
</tr>
<tr>
<td>Na(^+)</td>
<td>6.5</td>
<td>0.283</td>
</tr>
<tr>
<td>K(^+)</td>
<td>1.6</td>
<td>0.041</td>
</tr>
<tr>
<td>HCO(_3^-)</td>
<td>36.6</td>
<td>0.600</td>
</tr>
<tr>
<td>SO(_4^{2-})</td>
<td>29.0</td>
<td>0.302</td>
</tr>
<tr>
<td>Cl(^-)</td>
<td>14.0</td>
<td>0.395</td>
</tr>
</tbody>
</table>

pH = 7.4  
Dissolved Oxygen \((O_2(aq))\) = 0.8 mg/L  
Temperature = 25\(^0\)C

a) Do the concentrations reported in the analysis produce an acceptable charge balance error? (Show calculations used to arrive at your answer.) **No, the charge balance error is not acceptable. Cation meq/L = 1.46, Anion meq/L = 1.60, Ratio = 0.92**

b) What is the ionic strength of the water? (Show calculations.)  
\[ I = 2.4 \times 10^{-3} \]

c) Knowing that the cabins in the area, including yours, rely on septic tanks for wastewater disposal, list an additional analysis that should be conducted to determine the suitability of water for human consumption. **Nitrate (coliform bacteria would also be correct)**

d) The cabin does not currently have a water softener. Should you plan to install one? (Show calculations used to arrive at your answer.) **Hardness = 57, so the water is soft and does not need additional softening.**

e) Assuming that all redox reactions are in equilibrium with the half-reaction  
\[ \frac{1}{4}O_2(gas) + H^+ + e^- \rightleftharpoons \frac{1}{2}H_2O \]  
\[ pe^0 = +20.75 \]

and that the solubility of oxygen in water is controlled by the reaction  
\[ O_2(gas) \rightleftharpoons O_2(aq) \]  
\[ K = 1.29 \times 10^{-3} \]

calculate the pe of the water. (Note that the atomic weight of oxygen in 16.)  
\[ P_{O2} = (O_2)/(1.29 \times 10^{-2}) = (0.8 \text{ mg/L})/(32 \text{ g/mole}) = 2.5 \times 10^{-5} \text{ mol/L, } P_{O2} = 1.9 \times 10^{-2} \]

\[ pe = pe^0 - pH + \frac{1}{4} \log P_{O2} = 20.75 - 7.4 + \frac{1}{4}(-1.71) = 12.92 \]

f) Some of the pipes in the cabin are known to contain lead. Assume that lead concentrations are controlled by a redox reaction involving precipitation of PbO\(_2\)
\[
\frac{1}{2} PbO_{2(s)} + 2H^+ + e^- \leftrightarrow \frac{1}{2} Pb^{2+} + H_2O \quad \text{pe}^0 = +24.6 \text{ at } 25^\circ C
\]

and that this reaction occurs rapidly enough so that it is always at equilibrium.

Also assume that the precipitation of PbO$_2$ has a negligible effect on the pe or the pH of the water. Can leaching of lead from the pipes generate lead concentrations that exceed the drinking water standard of 0.05 mg/L?

Some additional, possibly helpful, information:

Atomic weight of lead = 207.19

You can assume that $\gamma_{Pb^{2+}} = 0.79$ at this ionic strength

\[
\frac{1}{2} \log [Pb^{2+}] = pe^0 - 2pH - pe = 24.6 - 2(7.4) - 12.92 = -3.12
\]

\[
[Pb^{2+}] = (10^{-3.12})^2 = 5.8 \times 10^{-7}
\]

\[
(Pb^{2+}) = [Pb^{2+}] / \gamma_{Pb^{2+}} = 7.3 \times 10^{-7} \text{ mole/L}
\]

Concentration in mg/L is $7.3 \times 10^{-7} \text{ mole/L} \times 207.19 \text{ g/mole} \times 1000 \text{ mg/g} = 0.15 \text{ mg/L}$

0.15 mg/L > 0.05 mg/L, so leaching of lead could exceed drinking water standard.