Chemistry 2000 Spring 2001 Section B Test 2 Solutions

1. (a) The liquid can only exist above the triple point. The triple point pressure is (from the graph) approximately 0.37 atm.

   (b) The normal boiling point is the equilibrium temperature at 1 atm. Again, we can just read this off the graph: $-108°C$.

   (c) The melting point increases with pressure indicating that the solid occupies a smaller volume than the liquid, i.e. that the solid is more dense.

2. The reaction ratio is
$$Q = \frac{(a_{CO})(a_{H_2})}{a_{H_2O}}.$$
   (The graphite is solid so its activity is 1.) In order for the reaction to proceed from left to right, we must have $Q < K$. Suppose that we take $P_{CO} = P_{H_2} = 0$ and any $P_{H_2O} > 0$. Then $Q = 0$, which is certainly smaller than K.

3. (a) KI is not volatile because it is an ionic compound.

   (b) Tartaric acid can form a number of hydrogen bonds to the solvent, so it is not volatile.

   (c) Bromine is nonpolar so it should be volatile.

4. Potassium hydroxide dissociates completely in water so $a_{OH^-} = 0.0032$.

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\begin{aligned}
a_{H^+} &= \frac{K_w}{a_{OH^-}} = \frac{1.47 \times 10^{-14}}{0.0032} = 4.6 \times 10^{-12}. \\
\therefore pH &= -\log_{10} a_{H^+} = 11.3
\end{aligned}
$$

5.
$$K_a = 10^{-pK_a} = 10^{-7.46} = 3.47 \times 10^{-8}.$$

   The K_a is quite small, so it is likely that a very small number of molecules of the acid will dissociate. Thus, $a_{HClO} \approx 0.05$. On the other hand, the acid is fairly concentrated, so we can probably safely ignore the water equilibrium. This implies that $a_{H^+} \approx a_{ClO^-}$. Therefore

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\begin{aligned}
K_a &= \frac{(a_{H^+})(a_{ClO^-})}{a_{HClO}} \approx \frac{(a_{H^+})^2}{a_{HClO}}. \\
\therefore 3.47 \times 10^{-8} &= \frac{(a_{H^+})^2}{0.05}. \\
\therefore (a_{H^+})^2 &= 1.73 \times 10^{-9}. \\
\therefore a_{H^+} &= 4.16 \times 10^{-5}. \\
\therefore pH &= -\log_{10}(a_{H^+}) = 4.38.
\end{aligned}
$$

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6. We need the mole fraction of water. To calculate this, we need to know the number of moles of solutes and solvent.

$$
\begin{aligned}
M_{(NH_4)_2SO_4} &= 2M_N + 8M_H + M_S + 4M_O = 132.13\,\text{g/mol.} \\
M_{H_2O} &= 18.015\,\text{g/mol.} \\
n_{(NH_4)_2SO_4} &= \frac{50\,\text{g}}{132.13\,\text{g/mol}} = 0.38\,\text{mol.} \\
\therefore n_{NH_4^+} &= 2(0.38\,\text{mol}) = 0.76\,\text{mol} \\
\text{and } n_{SO_4^{2-}} &= 0.38\,\text{mol.} \\
n_{H_2O} &= \frac{300\,\text{g}}{18.015\,\text{g/mol}} = 16.7\,\text{mol.} \\
X_{H_2O} &= \frac{16.7\,\text{mol}}{16.7 + 0.76 + 0.38\,\text{mol}} = 0.936. \\
\therefore P_{H_2O} &= X_{H_2O}\,P_{H_2O}^{\bullet} = (0.936)(7373\,\text{Pa}) = 6902\,\text{Pa.}
\end{aligned}
$$

7. The reaction is $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$, i.e. we get two HI's for every H_2 or I_2 used. This gives us the stoichiometric relationships

$$
\begin{aligned}
P_{HI} &= 2\left(P_{H_2,\text{initial}} - P_{H_2}\right) = 2\left(P_{I_2,\text{initial}} - P_{I_2}\right). \\
\therefore P_{H_2} &= P_{H_2,\text{initial}} - \frac{1}{2}P_{HI} \\
\text{and } P_{I_2} &= P_{I_2,\text{initial}} - \frac{1}{2}P_{HI}
\end{aligned}
$$

Since P and a only differ by a factor of 1 atm, these relationships apply equally well in terms of activities.

	a_{H_2}	a_{I_2}	a_{HI}
initial	2.75	1.50	0
final	1.355	0.105	2.79

The equilibrium constant is therefore

$$
K = \frac{a_{HI}^2}{(a_{H_2})(a_{I_2})} = \frac{2.79^2}{(1.355)(0.105)} = 54.7.
$$