CHEM102 Exam II (Jul 31 2009).
$33\frac{1}{3}$ points / problem with maximum of 100 points.

1.

a) $P_{H_2S}^{ini} = 100.0$ torr $= 0.1316$ atm; $P_{H_2O}^{eq} = 99.803$ torr $= 0.1313$ atm; $P_{O_2}^{ini} = 200.0$ torr $= 0.2632$ atm (4 sig. figs.). Write ICE table as follows:

	H$_2$S	O$_2$	SO$_2$	H$_2$O
I	0.1316 atm	0.2632 atm	0 atm	0 atm
C	$-x$	$-\frac{3}{2}x$	$+x$	$+x$
E	$0.1316 - x$ atm	$0.2632 - \frac{3}{2}x$ atm	x atm	x atm

The equilibrium pressure of water gives $x = 0.1313$ atm. Write the expression for K_p:

$$K_p = \frac{P_{SO_2}^{eq} \cdot P_{H_2O}^{eq}}{P_{H_2S}^{eq} \cdot \left(P_{O_2}^{eq}\right)^{3/2}} = \frac{(0.1313)^2}{(0.1316 - 0.1313) \cdot (0.2632 - \frac{3}{2} \cdot 0.1313)^{3/2}} = 3370.0$$

b) $K_p = K_c (RT)^{\Delta n} \Rightarrow K_c = K_p (RT)^{-\Delta n}$. $\Delta n = $ products $-$ reactants $=$ 2 - 2.5 $= -0.5$. Must use $R = 0.08206 \frac{\text{L atm}}{\text{mol K}}$ because this is compatible with the atm units used for K_p and L for K_c. Plugging in the numbers gives $K_c = 1.667 \times 10^4$ (with $T = 298$ K).

c) The new equation is rearranged by multiplying both sides by 2 and then reversing the reactants and products. The first step corresponds to squaring K_p and the second taking $1/K_p$. Thus the new $K_p' = 1/K_p^2 = 8.8052 \times 10^{-8}$.

d) $Q_p = \frac{P_{SO_2} \cdot P_{H_2O}}{P_{H_2S} \cdot P_{O_2}^{3/2}} = \frac{(0.1313 + 0.013158)(0.1313)}{(0.0003)(0.06625)^{3/2}} = 3708$. Since $Q_p > K_p$, the reaction proceeds from right to left to reach the new equilibrium.

e) $\Delta G_{rxn}^\circ = -RT \ln (K_p) = -(8.314 \frac{\text{J}}{\text{mol K}}) \times (298 \text{ K}) \ln (3370) = -21.12$ kJ/mol.

2.

a) It can donate 1, 2, or 3 protons depending on the conditions (acceptor).

b) $pK_a = -\log (K_a) \Rightarrow K_a = 10^{-pK_a}$. Inserting the pK_a values: $K_{a1} = 10^{-3.13} = 7.4 \times 10^{-4}$, $K_{a2} = 1.7 \times 10^{-5}$, $K_{a3} = 4.0 \times 10^{-7}$.

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c) $K_a \cdot K_b = 10^{-14}$ (at room temperature). Thus $K_b = \frac{10^{-14}}{K_a}$ and $K_{b1} = \frac{10^{-14}}{7.4 \times 10^{-4}} = 1.7 \times 10^{-11}$; $K_{b2} = 5.9 \times 10^{-10}$; $K_{b3} = 2.5 \times 10^{-8}$.

3.

a) Denote benzoic acid (weak acid) by BZH. To find out the pH, construct ICE table:

	BZH	H_2O	BZ^-	H_3O^+
I	1.0 M	–	0 M	0 M
C	$-x$	–	$+x$	$+x$
E	$(1.0 - x)$ M	–	x M	x M

$K_a = \frac{x^2}{1-x} \approx x^2 \Rightarrow x = \sqrt{2.5 \times 10^{-5}} = 5.01 \times 10^{-3}$ (less than 5% of 1; approximation OK). Since $[H_3O^+] = x = 5.01 \times 10^{-3}$ M then $pH = -\log([H_3O^+]) = 2.3$.

b) $pH + pOH = 14 \Rightarrow pOH = 14 - pH$ (at room temperature). This gives $pOH = 14 - 2.3 = 11.7$.

c) Note that H^+ and H_3O^+ are "synonyms" in water solutions. From the above $[H^+] = 5.01 \times 10^{-3}$ M and $[OH^-] = 2.00 \times 10^{-12}$ M because $K_w = [H_3O^+] \cdot [OH^-] = 10^{-14}$ (room temperature).