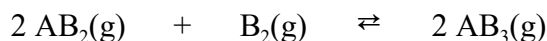


Name _____ KEY _____ Rec. Instr. _____

1. (3 pts) For the following reaction $K_c = 25.8$. The reaction is started with 1.000 mole of AB_3 , 2.000 moles of AB_2 and 1.000 mole of B_2 in a 2.000-L container. Determine if the reaction is at equilibrium or not? If not, which direction will it proceed to reach equilibrium? **Show work and explain!**



Determine reaction quotient, Q, and compare to K.

$Q = K$ system at equilibrium

$Q < K$ not at equilibrium - not enough product & too much reactant
shifts to right (forward) (----->) toward product to reach equil. (when $Q = K$)

$Q > K$ not at equilibrium - too much product & not enough reactant
shifts to left (reverse) (<-----) toward reactant to reach equil. (when $Q = K$)

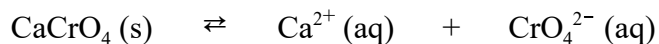
$$Q_c = \frac{[AB_3]^2}{[AB_2]^2 [B_2]} = \frac{(0.5000)^2}{(1.000)^2 (0.5000)} = 0.5000$$

$$Q_c = 0.5000 \quad K_c = 25.8$$

$Q_c < K_c$ **numerator** ([prod]) is **too small**, need to **inc numerator (products)**

\therefore rxn is **NOT** at **equilibrium**: Too much reactant and not enough product so the reaction proceeds to the **right toward products (forward direction)**

2. (9 pts) For the following reaction K_c equals 7.10×10^{-4} , at 25°C .



a) (4 pts) What are the **equilibrium** concentrations of Ca^{2+} and CrO_4^{2-} if solid CaCrO_4 is placed in water to form a saturated solution at 25°C ? (**Show the ICE table. State any assumptions made and check your percent error.**)

Use ICE (equil.) table (in Molarity)

	$\text{CaCrO}_4(\text{s})$	\rightleftharpoons	$\text{Ca}^{2+}(\text{aq})$	+	$\text{CrO}_4^{2-}(\text{aq})$
initial	C		0 M		0 M
change	-x		+ x		+ x

equil	constant		+ x		+ x

$$K_c = [\text{Ca}^{2+}] \cdot [\text{CrO}_4^{2-}] = 7.10 \times 10^{-4}$$

$\text{CaCrO}_4(\text{s})$ doesn't appear in K
(pure solids and liquids do not appear in K)

$$x^2 = 7.10 \times 10^{-4}$$
$$x = (7.10 \times 10^{-4})^{1/2} = 2.6645 \times 10^{-2} \text{ M}$$

$$[\text{Ca}^{2+}] = [\text{CrO}_4^{2-}] = 2.66 \times 10^{-2} \text{ M} \quad (3 \text{ s.f.})$$

***** cont. on next page *****

2. (Cont.)

b) (1 pts) For the system at equilibrium, what happens when $\text{CaCl}_2(\text{s})$, a soluble compound, is added?? (i.e. does the equilibrium shift and if so in what direction? If no shift then why not.) **EXPLAIN!**

$\text{CaCl}_2(\text{s})$ dissolves to give Ca^{2+} and 2 Cl^- ions. The Cl^- does nothing since it's not part of the equilibrium. The Ca^{2+} is an aqueous product. **Adding a product** shifts the reaction to the **LEFT**. When something is **added** (other than a pure solid or liquid) the reaction **shifts away** from the **added** substance to use it.

<u>Reactant</u>	<u>Product</u>	<u>Shift</u>
Add	Remove	Right
Remove	Add	Left

Shift: **AWAY** from what is **ADDED**

Shift: **TOWARD** what is **REMOVED**

NOTE: **K** remains **constant** for changes in conc. & pressure (Numerical value of **K** changes only for temp. changes.)

NOTE: Adding or Removing small amounts of **Pure SOLIDS** of **LIQUIDS** (as long as some is present) does **NOT** affect the equil.

This is because the conc. of pure solids and liquids are constant (even though the amounts can change) and do **NOT** appear in **K** or **Q**.

If **ALL** of a pure solid or liquid is removed the reaction shifts to replace the solid or liquid.

However, if the reaction takes place in solution, increasing the volume of the solution by adding a liquid (usually solvent) causes the concentrations of solutes to decrease and thus shifts the rxn toward more moles in solution. Thus, the fact the reaction shifts when a pure liquid is added is due to an indirect effect, the change in moles of solute in solution.

NOTE: As a rxn shifts the concentrations and amounts change. In this example, Ca^{2+} is added and the reaction shifts to the left. As it shifts to the left, the conc. of Ca^{2+} at that moment goes down (but in the new equil. the conc. winds up more than what was present in the original equilibrium because some was added). The conc. of CrO_4^{2-} dec. so it's new conc. is less than in the original equilibrium. The conc. of the CaCrO_4 solid does NOT change. However, it's amount (mass) does change. When the rxn shifts to the left more of this solid is produced so it's amount does change (it's mass increases).

This means the $\text{CaCrO}_4(\text{s})$ will be less soluble in the presence of Ca^{2+} or CrO_4^{2-} .

This is what's referred to as a "common-ion" effect. This will be discussed in detail in section 17.5.

***** cont. on next page *****

2. (Cont.)

c) (1 pts) For the system at equilibrium, what happens when **water** is **added** to the system? (i.e. does the equilibrium shift and if so in what direction? If no shift then why not.) **EXPLAIN!**

Normally, when you had a pure liquid no change occurs. However, when a reaction occurs in solution adding liquid can change concentrations of all substances in solution.

Since this is an aqueous reaction H_2O is the solvent. When more solvent is added the volume of solution increases and the concentrations of all substances in solution decrease (dilution). The reaction then shifts toward more moles of substances dissolved in solution. This is similar to what happens with gases, increasing volume causes a decrease in pressure (and conc.) which causes the reaction to shift toward more moles of gas.

For an **INC.** in **Volume of Solvent** (dilution), the reaction shifts toward **MORE moles of dissolved substances (solutes)**. Since the **products** have **more moles of dissolved substances (solutes)** the reaction will shift **RIGHT** (in the forward direction) toward **MORE moles of solutes**.

This makes sense. More solvent is added and more of the solid dissolves. Think about what happens when you remove solvent (allow it to evaporate). The solute starts to come out of solution as the solid.

Volume changes cause the following shifts for both liquid and gaseous solutions:

Volume dec (Conc. inc.) \implies shifts toward **fewer** moles of solutes in solution

Volume inc (Conc. dec.) \implies shifts toward **more** moles of solutes in solution

Changes in volume do **not affect liquids, solids** (their conc. do not change w. V like conc. of solutes do)

If **no change** in **moles of solutes** changes in **Volume** have **no effect**

d) (1 pts) For the system at equilibrium, what happens when part of the $CaCrO_4$ is **removed**? (i.e. does the equilibrium shift and if so in what direction? If no shift then why not.) **EXPLAIN!**

No shift. Normally if you remove something the equil. would shift toward what's removed. However, this is a solid. The **conc.** of a **solid** is **constant** so adding some or removing part of it does not change it's conc. so it has **no affect** on the equil. The solid does not appear in Q or K so it has no affect on the equilibrium if more is added or some is removed (as long as some still remains). The amount (mass) of the solid changes but it's conc. doesn't so the reaction doesn't shift.

NOTE: Adding or Removing small amounts of **Pure SOLIDS** of **LIQUIDS** (as long as some is present) does **NOT affect** the equil.

This is because the conc. of pure solids and liquids are constant (even though the amounts can change) and do **NOT** appear in K or Q.

If **ALL** of a pure solid or liquid is removed the reaction shifts to replace the solid or liquid.

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2. (Cont.)

e) (2 pts) Assuming the above reaction is endothermic, what happens when the temperature increases? (i.e. does the equilibrium shift and if so in what direction? If no shift then why not.) Also, what happens to the value of K? **EXPLAIN!**



For temperature changes you treat heat as a reactant or product. Also, changes in temperature are the only changes that cause a numerical change in the equilibrium constant, K.

Since the rxn. is endothermic **heat** is a **reactant**. This is heat coming from the surroundings. You inc. temp by adding more heat (e.g. from a Bunsen burner). Move **AWAY from ADDED**. That means the reaction **shifts** to the **right** (forward direction). As it does, the conc. of products increases and conc. of reactants decreases. These changes actually take place because the numerical value of the **equilibrium constant, K, increases**, due to the **temp. inc.** You can think of it as the rxn shifts right and results in more product and less reactant and since temp. or heat are not explicitly in the expression for K the numerical values of K had to inc. in order to get more product and less reactant (a shift to the right).

In this case the “conc.” of the solid doesn’t change but it’s amount does. As the reaction shifts to the right the amount (mass) of the solid reactant does change (dec.) but it’s conc. doesn’t.

Remember:

$\Delta H < 0$ (-); **exothermic**; **heat** is a **product**
- inc T (add heat, a product), shift left (K dec)
- dec T (remove heat, a product), shift right (K inc)

$\Delta H > 0$ (+); **endothermic**; **heat** is a **reactant**
- inc T (add heat, a reactant), shift right (K inc)
- dec T (remove heat, a reactant), shift left (K dec)

$\Delta H < 0$

T ↑, ←, K ↓

T ↓, →, K ↑

T & K move in
opposite direction

Product favored by
LOW T

$\Delta H > 0$

T ↑, →, K ↑

T ↓, ←, K ↓

T & K move in
same direction

Product favored by
HIGH T

3. (9 pts) For the following reaction K_c equals 5.35×10^2 at 80°C .



a) (4pts) What are the **equilibrium** concentrations of PH_3 and BCl_3 if 1.000 mole of each is placed in a 0.500-L vessel and allowed to react until equilibrium is reached? (**Show the ICE table. When appropriate, state any assumptions made and check your percent error.**)

NOT on Carmen quiz - just for practice

Use ICE (equil.) table (in Molarity when dealing w. K_c)

	$\text{PH}_3(\text{g})$	+	$\text{BCl}_3(\text{g})$	\rightleftharpoons	$\text{NH}_4\text{HS}(\text{s})$
initial	2.00 M		2.00 M		0
change	- x		- x		+ x

equil	2.00 - x		2.00 - x		+ x

$$K_c = \frac{1}{[\text{PH}_3] \cdot [\text{BCl}_3]} = 5.35 \times 10^2 \quad \text{NH}_4\text{HS}(\text{s}) \text{ doesn't appear in K}$$

(pure solids and liquids do not appear in K)

$$1/(2.00 - x)^2 = 5.35 \times 10^2$$

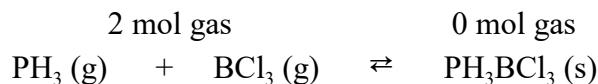
$$2.00 - x = (1.869 \times 10^{-3})^{1/2} = 4.3233 \times 10^{-2} \text{ M} \quad (x = 1.956)$$

$$[\text{PH}_3] = [\text{BCl}_3] = 4.32 \times 10^{-2} \text{ M}$$

***** continued on next page *****

3. (Cont.)

b) (1 pt) For the system at equilibrium, what happens to the reaction when the **pressure** is **increased** by adding Ne (an inert gas) at **constant temperature** and **volume**? (i.e. does the equilibrium shift and if so in what direction? If no shift then why not.) **EXPLAIN!**



NO Effect: Adding an inert gas which doesn't take part in the reaction or react with a substance in the reaction) has no effect. The total pressure increases but since the temp and vol are constant the partial pressures of the two reactant gases don't change and thus the reaction doesn't shift.

What if the pressure increase is because of a volume change:

Increase pressure (by decreasing volume): Shifts to **right** (2 mol gas ---> 0 mol gas)

Increase pressure (by decreasing volume) : **shift** to the side with **fewer moles** of gas.

For Pressure changes (due to volume changes):

P inc ==> **fewer moles gas** (this is equivalent to the Molarity inc., shift to side with fewer moles in soln)

P dec ==> **more moles gas** (this is equivalent to the Molarity dec., shift to side with more moles in soln)

Changes in Pressure do **not affect liquids, solids** or **aqueous** (their conc. do not change w. P like conc. of gases do)

If **no change** in **moles gas** changes in **P** have **no effect**

NOTE: This is really a conc. effect. Pressure is inversely proportional to the volume. It is directly proportional to the molarity (which is inversely prop. to the volume), $P = M \cdot RT$. When the volume changes the molarity changes as does the pressure. Whether it's a gaseous solution or a liquid solution changing volume can shift the reaction.

Volume dec. (molarity inc.) ==> **shifts toward fewer moles of gas or solutes in soln**

Volume inc. (molarity dec.) ==> **shifts toward more moles of gas or solutes in soln**

***** continued on next page *****

3. (Cont.)

c) (1 pt) For the system at equilibrium, what happens to the reaction when PH_3 is **added**? (i.e. does the equilibrium shift and if so in what direction? If no shift then why not.) **EXPLAIN!**

Shifts to the **right** (forward direction) to **use** some of the **added** substance. When you **add** something (other than a pure solid or liquid) the reaction **shifts away** from **added** substance to use part of it.

<u>Reactant</u>	<u>Product</u>	<u>Shift</u>
Add	Remove	Right
Remove	Add	Left

Shift: **AWAY** from what is **ADDED**

Shift: **TOWARD** what is **REMOVED**

NOTE: **K** remains **constant** for changes in conc. & pressure (Numerical value of **K** changes only for temp. changes.)

NOTE: Adding or Removing small amounts of **Pure SOLIDS** of **LIQUIDS** (as long as some is present) does **NOT** affect the equil.

This is because the conc. of pure solids and liquids are constant (even though the amounts can change) and do **NOT** appear in **K** or **Q**.

If **ALL** of a pure solid or liquid is removed the reaction shifts to replace the solid or liquid.

However, if the reaction takes place in solution, increasing the volume of the solution by adding a liquid (usually solvent) causes the concentrations of solutes to decrease and thus shifts the rxn toward more moles in solution. Thus, the fact the reaction shifts when a pure liquid is added is due to an indirect effect, the change in moles of solute in solution.

NOTE: As a rxn shifts the concentrations and amounts change. In this example, PH_3 is added and the reaction shifts to the right. As it shifts to the right the conc. of PH_3 at that moment goes down (but the conc. winds up more than what was present in the original equilibrium). The conc. of BCl_3 dec. so it's new conc. is less than the original. The conc. of the PH_3BCl_3 solid does **NOT** change. However, it's amount (mass) does change. When the rxn shifts to the right more of this solid is produced so it's amount does change (it's mass inc.).

d) (1 pt) For the system at equilibrium, what happens to the reaction when **all** the PH_3BCl_3 is **removed**? (i.e. does the equilibrium shift and if so in what direction? If no shift then why not.) **EXPLAIN!**

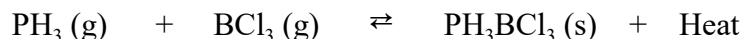
Shifts Right. This a solid. The conc. of a solid is constant so adding some or removing part of it does not change it's conc. so it has no affect on the equil. The solid does not appear in **Q** or **K** so it has no affect on the equilibrium if some more is added or some is removed (as long as some is present). The amount (mass) of the solid changes but it's conc. doesn't so the reaction doesn't shift.

However, you MUST have **some solid** to be at **equilibrium**. If **ALL** of a **pure solid** or **liquid** is **removed** the reaction **shifts** to **replace** the **solid** or **liquid**.

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3. (Cont.)

e) (2 pts) Assuming the above reaction is exothermic, what happens when the temperature decreases? (i.e. does the equilibrium shift and if so in what direction? If no shift then why not.) Also, what happens to the value of K? **EXPLAIN!**



For temperature changes you treat heat as a reactant or product. Also, changes in temperature are the only changes that cause a numerical change in the equilibrium constant, K.

Since the rxn. is exothermic **heat** is a **product**. This is heat coming from the reaction being released to the surroundings. You dec. temp by removing heat (e.g. place in an ice bath). Move **TOWARD REMOVED**. That means the reaction **shifts** to the **right (forward direction)**. As it does, the amount of products increases (conc. is constant) and conc. of reactants decreases. These changes actually take place because the numerical value of the **equilibrium constant, K, increases**, due to the **temp. dec.** You can think of it as the rxn shifts right and results in more product and less reactant and since temp. or heat are not explicitly in the expression for K the numerical value of K had to inc. in order to get more product and less reactant (a shift to the right).

In this case the “conc.” of the solid doesn’t change but it’s amount does. As the reaction shifts to the right the amount (mass) of the solid reactant does change (inc.) but it’s conc. doesn’t.

Remember:

$\Delta H < 0$ (-); **exothermic**; **heat** is a **product**
- inc T (add heat, a product), shift left, K dec
- dec T (remove heat, a product), shift right, K inc

$\Delta H > 0$ (+); **endothermic**; **heat** is a **reactant**
- inc T (add heat, a reactant), shift right, K inc
- dec T (remove heat, a reactant), shift left, K dec

$\Delta H < 0$

T ↑, ←, K ↓

T ↓, →, K ↑

T & K move in
opposite direction

Product favored by
LOW T

$\Delta H > 0$

T ↑, →, K ↑

T ↓, ←, K ↓

T & K move in
same direction

Product favored by
HIGH T

4. (2 pts) What is(are) the difference(s) between the **Arrhenius** and **Bronsted-Lowry** definitions of a **base**? **Not on quiz - just for practice.**

Arrhenius base: A substance that has OH^- (hydroxide ion), in the formula and when dissolved in water, increases the concentration of OH^- ions. **Restricted to aqueous solutions.**

Although the book states NH_3 is an Arrhenius base this is technically **NOT** truly an Arrhenius base in the fundamental sense of the definition. It has no OH in the formula. When put NH_3 in water it does increase the conc. of OH^- . The book uses this looser definition to state NH_3 is an Arrhenius base (it is **not**). Arrhenius himself didn't consider it a base. In order to do so he had to come up with the substance ammonium hydroxide, NH_4OH , which does **NOT** actually **exist**. If you put NH_3 in H_2O you do get NH_4^+ and OH^- ions. However, if you evaporate the water you do not get solid NH_4OH . Instead as the water evaporates the NH_3 comes out as a gas. Still to this day you may see the name ammonium hydroxide on a bottle of aqueous ammonia (NH_3 dissolved in H_2O). Ammonium hydroxide solution is a misnomer (named incorrectly), since it doesn't actually exist, not even in solution (in solution you have ammonium ions and hydroxide ions but not ammonium hydroxide).

Bronsted-Lowry base: A substance (molecule or ion) that can **accept** a **proton**, H^+ , from another substance. This theory is about proton transfer reactions. It is **NOT restricted to aqueous solutions**, whereas Arrhenius theory is. This theory also introduced the idea about **conjugate acid-base pairs**.

Proton Acceptor

This theory covers all Arrhenius acids and bases. BL theory deals with proton-transfer reactions. That's a good way to think about it. The stronger acid of the two reactants transfers a proton to the other reactant (which would act as the base).

Lewis base: A substance (molecule or ion) that can **donate** a pair of electrons to another substance (although the electrons themselves are not transferred). It is **NOT restricted to aqueous solutions**, whereas Arrhenius theory is.

Electron-pair Donor

This is the most comprehensive theory of the three. It covers all BL acids and bases (and Arrhenius acids and bases) and reactions which can explain why things w/o hydrogens in the formula can cause a solution to be acidic. The LB is not actually losing free electrons, it combines with something that needs a pair of electrons because it's electron deficient.

NOTE: The e^- pair is not actually transferred from the base to the acid. They combine and share the pair of e^- .

For these theories, an Arrhenius acid or base is a BL acid or base and a BL acid or base is a Lewis acid or base but it doesn't necessarily go back in the other direction (i.e. a Lewis acid or base is not necessarily a BL acid or base).

5. (3 pts) What is the **conjugate acid** of $\text{H}_2\text{P}_2\text{O}_7^{2-}$?

$\text{H}_2\text{P}_2\text{O}_7^{2-}$ is amphoteric - can act as an acid or a base. You are told to treat it as an acid in this case.

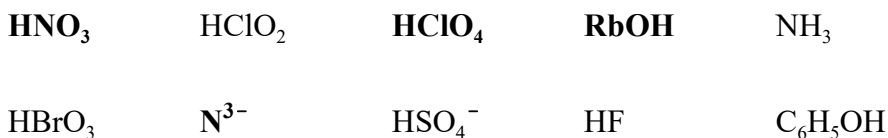
To get the **conjugate base** of an **acid** you simply **REMOVE** an H^+ from the acid:



To get the **conjugate acid** of a **base** you simply **ADD** an H^+ to the base:



6. (2 pts) Which of the following are **strong** acids or **strong** bases? (Circle all that apply.)



The 7 strong acids are: HCl , HBr , HI binary acids
 HNO_3 , HClO_3 , HClO_4 , H_2SO_4 (1st H^+ only) oxyacids (ternary)

Strong bases are all group 1 A and soluble group 2 A (Ca and below) hydroxides & bases stronger than OH^- (some examples are below)

O^{2-} (conj base of OH^-), H^- (conj base of H_2 - a neutral molecule)

NH_2^- (conj base of NH_3 , itself a base), NH^{2-} (conj base of NH_2^-), N^{3-} (conj base of NH^{2-})

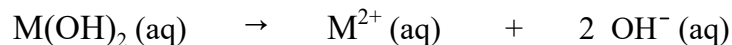
S^{2-} (conj base of SH^- , itself the conj base of H_2S)

CH_3^- (conj base of CH_4 , a neutral nonionizing molecule in H_2O)

CH_3O^- (conj base of CH_3OH , a neutral nonionizing molecule in H_2O)

7. (5 pts) A saturated solution of Ca(OH)_2 has a $[\text{Ca}^{2+}]$ of 0.15 M. What is the pH of the solution? (atomic weights: Ca = 40.08, O = 16.00, H = 1.008)

For group 2A hydroxides you have to be careful when determining the conc. of OH^- . There are 2 OH^- groups for every 1 M(OH)_2 .



$$[\text{M}^{2+}] = [\text{M(OH)}_2]$$

$$[\text{OH}^-] = 2 [\text{M(OH)}_2] \quad \text{since there are 2 OH}^- \text{ for each formula unit of M(OH)}_2 \text{ and each M}^{2+}$$

For a soln of Ca(OH)_2 with a $[\text{Ca}^{2+}] = 0.15 \text{ M}$ we first find the conc. of OH^- .

$$[\text{OH}^-] = 2 [\text{Ca(OH)}_2] = 2 (0.15 \text{ M}) = 0.30 \text{ M}$$

$$\text{pOH} = -\log [\text{OH}^-] = -\log (0.30) = 0.5228$$

$$\text{pOH} = \text{pK}_w - \text{pH} = 14.00 - 0.5228 = 13.4771 = 13.48 \quad (2 \text{ s.f., the numbers to the right of the decimal pt.})$$

8. (6 pts) A 0.0100 M solution of an acid is 19.0% ionized at 25 °C. **Show all work or explain!**

Want the **ionization constant**, K_a , for a weak acid given the conc. of the acid and the % ionization.

a) What are the $[H^+]$ and **pH** of this solution?

$$\% \text{ ionization} = \frac{[H^+]_{\text{eq}}}{[HA]_{\text{orig}}} \times 100$$

$$[H^+]_{\text{eq}} = \frac{\% \text{ ionization}}{100} \times [HA]_{\text{orig}} = \frac{19}{100} (0.010) = 0.0019$$

$$19 \% = \frac{[H^+]_{\text{eq}}}{0.0100} \times 100\%$$

$$[H^+]_{\text{eq}} = 1.90 \times 10^{-3} \text{ M} = 1.9 \times 10^{-3} \text{ M}$$

$$\text{pH} = -\log [H^+] = -\log (1.9 \times 10^{-3}) = 2.7212 = 2.72 \text{ (only 2 s.f. - to right of decimal)}$$

b) What is the K_a for the acid? **Show the ICE table.**

Technically you don't need to write out an ICE table for this but it does make the problem easier. In this case you won't be solving for H^+ (H_3O^+) but instead use it to solve for K_a .

HA is a weak acid - weak acid equil. problem - **Use equil. (ICE) table** (in Molarity)

	HA	\rightleftharpoons	H ⁺	+	A ⁻	(or HA + H ₂ O \rightleftharpoons A ⁻ + H ₃ O ⁺)
initial	0.010		0		0	
change	- x		+ x		+ x	

equil	0.010 - x		x		x	

$$x = [H^+] = [H_3O^+]$$

get this from % ionized:

$$K_a = \frac{[H^+][A^-]}{[HA]} = \frac{x^2}{0.010 - x} = \frac{(0.0019)^2}{(0.010 - 0.0019)} = 4.456 \times 10^{-4} = 4.5 \times 10^{-4}$$

Can **not** ignore the "x" in the 0.010 - x and get the correct answer. There is no point in ignoring the "x" in this problem since you have "x" so just use it. If you did, you would get 3.6×10^{-4} which would be a 19% error.

9. (11 pts) You have a solution of 0.0942 M aniline, $C_6H_5NH_2$, with $K_b = 4.3 \times 10^{-10}$, at $25^\circ C$. (**Show the ICE table, state any assumptions made and check your percent error.**) **Show all work or explain!**

a) What are $[H^+]$, $[OH^-]$, pH and pOH in this solution?

$C_6H_5NH_2$ is a weak base - weak base equil. problem - **Use equil. table** (in Molarity)

	$C_6H_5NH_2$	+	H_2O	\rightleftharpoons	$C_6H_5NH_3^+$	+	OH^-
initial	0.0942				0		0
change	- x				+ x		+ x
equil	0.0942 - x				x		x

$$K_b = \frac{[C_6H_5NH_3^+][OH^-]}{[C_6H_5NH_2]} = 4.3 \times 10^{-10} \quad \frac{x^2}{0.0942 - x} = 4.3 \times 10^{-10}$$

Assume $0.0942 \gg x$, so $(0.0942 - x) \approx 0.0942$ $\frac{x^2}{0.0942} = 4.3 \times 10^{-10}$

$$x = [OH^-] = \underline{6.36 \times 10^{-6}} = 6.4 \times 10^{-6} \text{ M}$$

$$\% \text{ error} = \frac{6.4 \times 10^{-6}}{0.0942} \times 100\% = 0.0068 \% \text{ error (assumption above is okay)}$$

$$\text{pOH} = -\log(6.4 \times 10^{-6}) = \underline{5.196} = \underline{5.20} \quad (2 \text{ s.f.} - 2 \text{ digits to right of decimal point})$$

$$\text{pH} + \text{pOH} = \text{pK}_w = 14.00$$

$$\text{pH} = 14.00 - 5.20 = \underline{8.80} \quad ("2" \text{ s.f.})$$

$$[H^+] = 10^{-\text{pH}} = 10^{-8.80} = \underline{1.57 \times 10^{-9}} \text{ M}$$

$$[H^+] \times [OH^-] = K_w = 1.0 \times 10^{-14}$$

$$\text{or} \quad [H^+] = \frac{1.0 \times 10^{-14}}{6.4 \times 10^{-6}} = \underline{1.571 \times 10^{-9}} \text{ M}$$

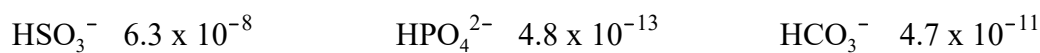
$$\text{pH} = -\log(1.571 \times 10^{-9}) = 8.80$$

NOTE: The **significant figures** in the **pH**, **pOH** and **pK** are to the **right** of the **decimal point**.

b) What is the **percent ionization** for $C_6H_5NH_2$ in this solution?

$$\% \text{ ionization} = \frac{[OH^-]}{[C_6H_5NH_2]_{\text{orig}}} \times 100\% = \frac{6.4 \times 10^{-6}}{0.0942} \times 100\% = \underline{0.0068} \% \text{ ionized}$$

10. (3 pts) Given the following K_a values, determine which species is the **strongest base**. **Explain!**



Remember:

Larger $K_a \implies$ smaller $\text{p}K_a \implies$ stronger acid \implies weaker conj. base

Larger $K_b \implies$ smaller $\text{p}K_b \implies$ stronger base \implies weaker conj. acid

For a conj. Acid-Base pair:

$$K_a \times K_b = K_w \qquad \text{and} \qquad \text{p}K_a + \text{p}K_b = \text{p}K_w$$

$$K_a = 6.3 \times 10^{-8} \qquad K_b = 1.6 \times 10^{-7}$$

$$K_a = 4.8 \times 10^{-13} \qquad K_b = 2.1 \times 10^{-2}$$

$$K_a = 4.7 \times 10^{-11} \qquad K_b = 2.1 \times 10^{-4}$$

HSO_3^- strongest acid (largest K_a) \implies weakest conj. base, SO_3^{2-} (smallest K_b)

HPO_4^{2-} weakest acid (smallest K_a) \implies **strongest conj. base, PO_4^{3-}** (largest K_b)