Name: ______________________________ Block: ____________

IV. Acids & Bases (part 2)

IV.7 Ionization constant of water– K_w

You will be able to:

- Write equations representing the ionization of water using either H_3O^+ and OH^-, or H^+ and OH^-
- Predict the effect of the addition of an acid or base to the equilibrium system: $2H_2O \leftrightarrow H_3O^+ + OH^-$
- State the relative concentrations of H_3O^+ and OH^- in acid, base, and neutral solutions
- Write the equilibrium expression for the ion product constant of water (water ionization constant: Kw)
- State the value of Kw at 25°C
- Describe and explain the variation in the value of Kw with temperature
- Calculate the concentration of H_3O^+ (or OH^-) given the other, using Kw

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STRONG ACID + **STRONG BASE** ⇄ SALT + **WATER** + HEAT

Example: $HCl_{(aq)} + NaOH_{(aq)} \rightleftarrows NaCl_{(aq)} + H_2O_{(l)} + 59kJ$

Complete ionic equation: $H^+_{(aq)} + Cl^-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)} \rightleftarrows Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$

Net ionic equation: ____

Reverse equation **is the SELF-IONIZATION OF WATER**	____, or ____

Write the K_{eq} expression for this equilibrium:

$K_{eq} = K_w =$

Definitions:

NEUTRAL solution ________________________________

ACIDIC solution ________________________________

BASIC solution ________________________________

Since reaction is *endothermic:* $59KJ + 2H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + OH^-_{(aq)}$

As temp increases: shifts ________________, ________________ are favoured,

- $[H_3O^+]$, $[OH^-]$, and K_w ________________________
- pH, pOH, and pKw ________________________ (details later).

As temp decreases: shifts ________________, __________________ are favoured,

- $[H_3O^+]$, $[OH^-]$, and K_w ______________________
- pH, pOH, and pKw ______________________ (details later).

Relative concentrations of H_3O^+ and OH^- in solutions:

Example 12: Calculate $[OH^-]$ in 0.00600 M HNO_3 at 60^0C. Kw at $60^0C = 9.55 \times 10^{-14}$

Step 1: Remember $[H_3O^+]$ = [strong acid]	
Step 2: Write out Kw expression at temp	
Step 3: Solve for [OH-]	

Example 13: Find $[H_3O^+]$ in 0.020 M $Ba(OH)_2$ at 25ºC.

Step 1: Remember $[OH^-]$ = [base] x # of OH's	
Step 2: Write out Kw expression at temp	
Step 3: Solve for $[H_3O^+]$	

Do Hebden set 25: p. 127 #28, 29abc, 30cd

IV.8-9 K_a and K_b

You will be able to:

- Write Ka and Kb equilibrium expressions for weak acids or weak bases
- Relate the magnitude of Ka or Kb to the strength of the acid or base
- Calculate the value of Kb for a base given the value of Ka of its conjugate acid (and vice versa)

The K_a is the *acid ionization constant* of a WEAK acid. For example,

Write the ionization of boric acid in water: ______________________________

The equilibrium expression for the ionization is: **K_a** =

According to the *table of relative strengths*, **K_a** =

The **larger** the **Ka,** the ______________________ the ACID.
The **smaller** the **Ka,** the ______________________ the ACID.

**For STRONG ACIDS, the Ka is "very large". Explain why.*

<u>The K_b is the *base ionization constant* of a WEAK base.</u> For example,

Write the ionization of ammonia in water: ______________________________

The equilibrium expression for the ionization is: **K_b** =

The table of relative strengths only lists the Ka!

Luckily, there is a relationship between **conjugate pairs**!

For a **CONJUGATE PAIR:** **K_a (conj acid) x K_b (conj base) = K_w**

Using this equation, you can find the K_b values for weak bases from the table!

Example 14: Calculate the K_b of HCO_3^- at 25ºC.

Step 1: Look down the RIGHT (base) side of table until you find it. Write out the ionization of its CONJUGATE ACID.	
Step 2: Write out the Kb expression as its relationship to the Ka of its conj base.	
Step 3: Solve for Kb	

K_a and K_b can be compared against each other!

The **greater** the **K_a** value, the ____________________the **acid.**

The **greater** the **K_b** value, the ___________________ the **base**.

<u>Using K_a and K_b to differentiate amphiprotic actions:</u>

Example 15: When $HC_2O_4^-$ reacts with water, will it preferrentially act as an ACID or a BASE?

Step 1: Write out the ionization equations for amphiprotic substance acting as an acid and a base	As an ACID: As a BASE:
Step 2: Find the Ka and Kb values for each ionization. Solve for Kb.	
Step 3: Compare Ka and Kb. Larger value will determine action.	

<u>Sample calculation involving K_a and the WEAK</u> (there will be many more of these coming up...)

Example 16: Find the $[H_3O^+]$ in 0.10 M HF.

Step 1: Write out equilibrium equation for *ionization*	
Step 2: Set up ICE table	
Step 3: Write out the Ka expression	
Step 4: State assumption	
Step 5: Solve for x ($[H_3O^+]$)	

Do Hebden set 26: p. 128 #31b, 32a, 33-35ab

IV.10 Relative Strengths of Acids and Bases

(already covered in Part 1 -- *"Will equilibrium favour products or reactants?")*

Summary: In a B-L acid-base equilibrium, the side that has the ___________________ acid/base will be favoured.

"Strong PUSH the weak"

A **second method** for determining which side is favoured uses K_a:

$$\frac{[\text{products}]}{[\text{reactants}]} = K_{eq} = \frac{K_a \text{ (reactant acid)}}{K_a \text{ (product acid)}}$$

You only have to use one method, so pick whichever one works for you!

Relating K_{eq} to acid-base equilibrium

If products are favored K_{eq} is large (>1)

If reactants are favored K_{eq} is small (<1)

IV.11 pH and pOH

You will be able to:

- Define pH and pOH
- Define pKw, give its value at 25°C, and its relation to pH and pOH
- Calculate $[H_3O^+]$ or [OH-] from pH and pOH
- Describe the pH scale with reference to everyday solutions

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pH is a shorthand method of showing acidity (or basicity, alkalinity)

pH = *"**p**owers of 10 of [**H**$_3$O$^+$]*

If $[H_3O^+] = 0.10$ M (1.0×10^{-1} M) pH = 1.00
$[H_3O^+] = 0.00010$ M (1.0×10^{-4} M) pH = 4.00

What is the relationship between $[H_3O^+]$ and pH?

Definition of pH

pH =
pOH =

LOGS and ANTI-LOGS

This is a BRIEF summary of the math necessary for pH and pOH calculations.
If you want more, check Hebden p. 134-139. p

In this class, all our **log** values will always be **"logarithm to the base 10"**.

- **LOG** = ____
- **ANTILOG** = ____

$\log(10^x) = x$
$\text{antilog}(x) = 10^x$

CHECK your calculator!! LOG: Enter: 1 → EXP → 7 → +/- → LOG → +/- and the answer should be 7
ANTILOG: 4 → INV/2nd → LOG and the answer should be 1000

Question TYPE 1: Converting from $[H_3O^+]$ or [OH-] to pH and pOH

Example 17: Find the pH of 0.030 M HCl

Step 1: Write out equation for ionization. Remember, $[H_3O^+]$ = [strong acid]	
Step 2: Write out pH definition. Solve for pH. *Sig fig counting starts *after pH/pOH* decimal place.*	

Question TYPE 2: Converting from pH or pOH to $[H_3O^+]$ and [OH-]

Example 18: If pOH = 11.682, what is the [OH-] in $Ca(OH)_2$?

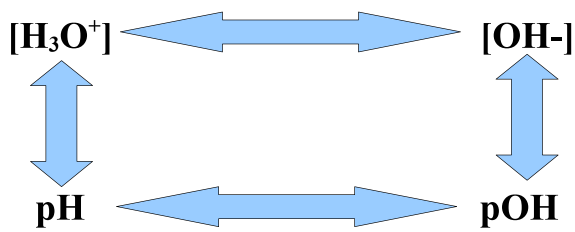
Step 1: Write out definition of pOH. Isolate [OH-] (conver to antilog).	
Step 2: Solve for [OH-].	
Step 3: Write out ionization equation. Remember, [OH-] = [strong base] x # OH's *Sig fig counting starts *after pH/pOH* decimal place.*	

pH and pOH Relationships

Derive the relationship of pH and pOH:

Write out the Kw expression and value at 25ºC	$K_w =$
Take the log of both sides	
Rewrite using: **log(A x B) = log(A) + log(B)**	
Plug in value of Kw	
Therefore,	
Remove negative (multiply by -1)	
Therefore,	

Use "the SQUARE" for calculations at 25ºC



SUMMARY:

At ALL temperatures:

$K_w =$ ______________________________

$pK_w =$ ______________________________

$pK_w =$ ______________________________

At 25ºC ONLY:

$K_w =$ ______________________________

$pK_w =$ ______________________________

$pK_w =$ ______________________________

Question TYPE 3: Calculate [OH-] from pH or $[H_3O^+]$ from pOH

Example 19: If pH = 6.330, what is the [OH-]?

Step 1: Calculate pOH from pH	
Step 2: Calculate [OH-] from pOH	

The pH Scale

At 25 ºC:

In **neutral** water	**pH = 7.0**
In **acid** solution	**pH < 7.0**
In **basic** solution	**pH > 7.0**

pH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
$[H_3O^+]$															
$[OH^-]$															
pOH	14														0

Pattens & trends:

1. As pH ________________________, pOH _________________________.
2. a) A solution is ____________________ when its **pH** is _____ 7 or **pOH** is _____ 7.

   b) A solution is ____________________ when its **pH** is _____ 7, or **pOH** is _____ 7.
3. The pH scale is **LOGARITHMIC,** so...
   - Each value on the pH scale represents a 10x difference.
   - When the **pH** is *increased* by **1**, the $[H_3O^+]$ is __________________________________.
4. In **neutral** water pH = pOH at any temp.
   - pH & pOH = 7.00 at 25^0C ONLY
   - At *lower temps*, pH and pOH are _____ 7
   - At *higher temps*, pH and pOH are _____ 7

Do Hebden set 27: p. 139 #49ab, 50abe, 51, 52; p. 141 #55abcd, 56abcd
(Very important to master these calculations!)

IV.12 Mixtures of STRONG Acids and Bases

You will be able to:

- Determine whether a solution is acidic, basic, or neutral depending on the relative amounts of reactants involved.

Example 20: If 15.0 mL of 0.100 M HBr is added to 25.0 mL of 0.100 M $Mg(OH)_2$, what is the pH of the resulting mixture?

Step 1: Write out ionization equations for both the SA and SB. Determine [ ] based on molar ratios.	
Step 2: Calculate diluted $[H_3O^+]$ and $[OH^-]$ using $C_1V_1=C_2V_2$	
Step 3: Determine excess ion ($[H_3O^+]$ and $[OH^-]$ should be 1:1, but one will be in excess from dilution)	
Step 4: Write out pH or pOH expression, determining which ion in excess.	
Step 5: Solve for pH	

Example 21: What mass of $Ca(OH)_2$ must be added to 500.0 mL of 0.0150 M HBr to create a solution with pH = 2.750? (Assume no volume change.)

Step 1: Determine the $[H_3O^+]$ from pH	
Step 2: Write expression for excess ion. Solve for diluted ion.	
Step 3: Convert [ ] to grams	

Do Hebden set 28: p. 143 #58-60, 63-65