Department of Chemistry
University of Texas at Austin

Name:_____

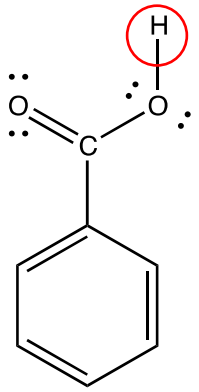
Aqueous Equilibria Unit Activity – Acids and Bases **KEY**

PART I
The following exercise will help you come to know acids and bases better.

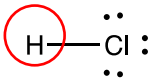
The following compounds are all acids:

What common features would help you identify these compounds as acids.
Most of these compounds have a COOH group and/or a very polar bond that includes a H atom such as H-Cl.
There are 3 types of acids:
oxy-acids (nitrous and nitric)
Carboxylic Acids: benzoic acid, acetic acid, formic acid
Hydro acid: HCl, HCN
Circle the acidic hydrogen on all compounds.
Match the name with the acid.

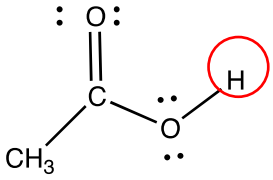
a) benzoic acid



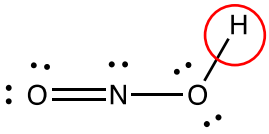
b) hydrochloric acid



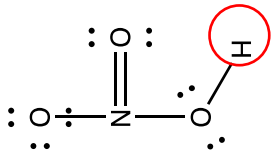
c) acetic acid



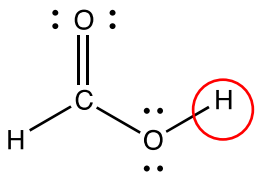
d) nitrous acid

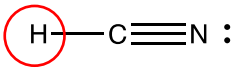


e) nitric acid



Name:_____

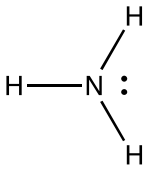
f) formic acid 

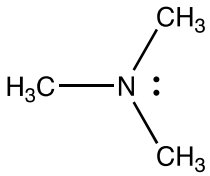
g) hydrocyanic 

The following compounds are all bases:

What common features would help you identify these compounds as bases?
Many of them have hydroxyl groups or a nitrogen (N) with a lone pair.
Match the name with the base:

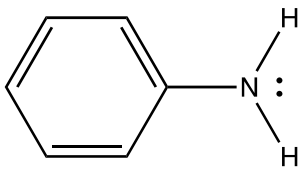
a) barium hydroxide $Ba(O\text{-}H)_2$

b) Ammonia 

c) trimethyl amine 

d) potassium hydroxide $K(O\text{-}H)$

e) sodium hydroxide $Na(O\text{-}H)$

f) phenyl amine (aniline) 

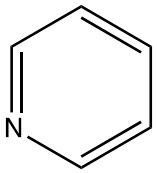
Based on your observations of some common acids and bases, predict whether the following compounds are acids or bases and why:

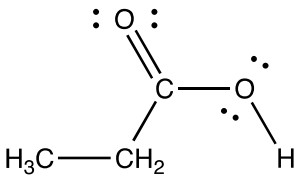
Name:_____

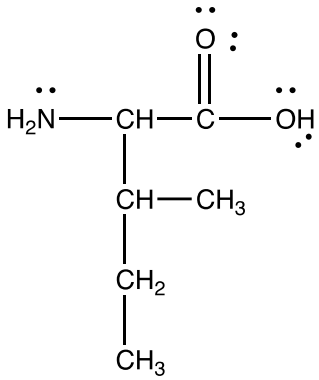
I) Base - N w/lone pair

II) Acid because of the COOH group

III) Both! COOH group and N w/lone pair







PART II

1. Examine the following data tables, looking for trends, inferences, etc.; then answer the questions. Be prepared to share you answers with the class.

Acid	Equilibrium Constant, K_a
$HClO_2$	1.2×10^{-2}
HF	7.2×10^{-4}
$C_5H_5NH^+$	5.8×10^{-6}
HOCl	3.5×10^{-8}
NH_4^+	5.6×10^{-10}
$CH_3NH_3^+$	2.3×10^{-11}

2. Please write the equation for the reaction that occurs when $HClO_2$ is placed in water.

   $HClO_2 + H_2O \rightarrow H_3O^+ + ClO_2^-$

3. Please write the equilibrium expression for $HClO_2$.

   $K = \frac{[ClO_2^-][H_3O^+]}{[HClO_2]}$

4. Please describe the concept of "acid strength".

   The stronger the acid, the more protons or H3O+ is in solution when a concentration of that acid is in solution. The more easily an acid is ionized or deprotonates, the stronger the acid it is.

5. Are the acids listed in order of increasing acid strength or decreasing acid strength?

These acids are in order of DECREASING strength.

Base	Equilibrium Constant, K_b
CH_3NH_2	4.38×10^{-4}
NH_3	1.8×10^{-5}
OCl^-	2.9×10^{-7}
C_5H_5NH	1.7×10^{-9}
F^-	1.4×10^{-11}
ClO_2^-	8.3×10^{-13}

6. Please write the equation for the reaction that occurs when CH_3NH_2 is placed in water.

$CH_3NH_2 + H_2O \rightarrow CH_3NH_3^+ + OH^-$

7. Please write the equilibrium expression for CH_3NH_2.

$$K = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]}$$

8. Please describe the concept of "base strength"?
   The stronger the base, the more hydroxide ions or OH- is in solution when a concentration of that base is in solution. The more easily an base is ionized or is protonated, the stronger the base it is.
9. Are the bases listed in order of increasing base strength or decreasing base strength?
   These bases are in order of DECREASING strength.
10. Can you see a correlation between the list of acids and the list of bases? If yes, what is it?
    Yes, the strongest acids (largest Ka's) correlate with the weakest bases (smallest Kb's). $HClO_2$ is the strongest acid, but has the weakest base strength when deprotonated.

11. Conjugate Acid-Base partners have a special relationship. Based on the Equilibrium Constant data can you determine and state that relationship?
    Strong acids ionize into the weakest conjugate bases and vice versa.

CLASS CHECK IN – WHOLE CLASS CHECK IN – WHOLE CLASS CHECK IN

Water behaves in a unique way. Because water is **amphiprotic**, capable of donating or accepting a proton, it can and does auto-ionize according to the following equation:

$$H_2O(l) + H_2O(l) \leftrightarrows H_3O^+(aq) + OH^-(aq)$$

12. Write the equilibrium constant expression for water.

Name:_____

$$K = \frac{[H_3O^+][OH^-]}{1}$$

13. Rewrite the expression for K_a for $HClO_2$.

$$K_a = \frac{[ClO_2^-][H_3O^+]}{[HClO_2]}$$

14. Write the K_b expression for ClO_2^-.

$$K_b = \frac{[HClO_2][OH^-]}{[ClO_2^-]}$$

15. Multiply the K_a expression times the K_b expression.

$$K_a \times K_b = \frac{[ClO_2^-][H_3O^+]}{[HClO_2]} \times \frac{[HClO_2][OH^-]}{[ClO_2^-]} = [H_3O^+][OH^-]$$

16. Compare your answer to the equilibrium expression for water.
It is the same expression!

17. Now input the values for K_a and K_b from the tables above, and multiply those values. From this calculation predict the value of K_w.
For $HClO_2$: $(1.2 \bullet 10^{-2})(8.3 \bullet 10^{-13}) = 9.96 \bullet 10^{-15}$
For NH_4^+: $(5.6 \bullet 10^{-10})(1.8 \bullet 10^{-5}) = 1.008 \bullet 10^{-14}$
For $C_5H_5NH^+$: $(5.8 \bullet 10^{-6})(1.7 \bullet 10^{-9}) = 9.86 \bullet 10^{-15}$

It appears that K_w is approximately $1.0 \bullet 10^{-14}$

CLASS CHECK IN – WHOLE CLASS CHECK IN – WHOLE CLASS CHECK IN