Chemical Reactions 4.8 Introduction to Acid-Base Reactions Worksheet Key

- 1) Label the acid, base, conjugate acid, and conjugate base in the following reactions.
 - a. $HNO_{3(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + NO_3^-_{(aq)}$ Acid Base Conjugate Conjugate
 Acid Base
 - b. $HCO_3^{-}_{(aq)} + OH^{-}_{(aq)} \rightleftharpoons CO_3^{-}_{(aq)} + H_2O_{(l)}$ Acid Base Conjugate Conjugate Base Acid
 - c. $H_2PO_4^-$ (aq) $+ H_2S_{(aq)} \rightleftharpoons H_3PO_{4(aq)} + HS^-$ (aq) Base Acid Conjugate Conjugate Acid Base
 - d. $HF_{(aq)} + H_2O_{(1)} \rightleftharpoons H_3O^+_{(aq)} + F^-_{(aq)}$ Acid Base Conjugate Conjugate Acid Base
 - e. $CN_{(aq)}^- + NH_{4(aq)}^+ \rightleftharpoons HCN_{(aq)} + NH_{3(aq)}$ Base Acid Conjugate Conjugate Acid Base
 - f. $HCN_{(aq)} + H_2O_{(1)} \rightleftharpoons H_3O^+_{(aq)} + CN^-_{(aq)}$ Acid Base Conjugate Conjugate Acid Base
 - g. $2 \text{ H}_2\text{O}_{(1)} \rightleftharpoons \text{OH}^-_{(aq)} + \text{H}_3\text{O}^+_{(aq)}$ Acid and Base Conjugate Conjugate
 Base Acid
 - h. $2 \text{ NH}_{3(aq)} \rightleftharpoons \text{ NH}_{4}^{+}_{(aq)} + \text{ NH}_{2}^{-}_{(aq)}$ Acid and Base Conjugate Conjugate
 Acid Base
 - i. $HClO_4(aq) + H_2O(l) \rightarrow ClO_4(aq) + H_3O^+(aq)$ Acid Base Conjugate Conjugate Base Acid
 - j. $HI(aq) + H_2O(l) \rightarrow I^*(aq) + H_3O^*(aq)$ Acid Base Conjugate Conjugate Base Acid

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2) What is the strongest base in each the following reactions? Provide justification based on solution equilibrium or forces of attraction between particles.

a.
$$HClO_{4(aq)} + H_2O_{(1)} \rightarrow ClO_{4(aq)} + H_3O_{(aq)}^+$$

 H_2O is the strongest base. Strong acids, such as $HClO_4$, experience ~100% dissociation and have weak conjugate bases. Thus, ClO_4^- is a weak base. H_2O and ClO_4^- compete for H^+ ions. H_2O acquires the H^+ ions most of the time, as the reaction goes to completion.

b.
$$HNO_{3(aq)} + H_2O_{(l)} \rightarrow NO_{3(aq)} + H_3O_{(aq)}^+$$

 H_2O is the strongest base. Strong acids, such as HNO_3 , experience ~100% dissociation and have weak conjugate bases. Thus, NO_3^- is a weak base. H_2O and NO_3^- compete for H^+ ions. H_2O acquires the H^+ ions most of the time, as the reaction goes to completion.

c.
$$2 \text{ H}_2\text{O}_{(1)} \rightleftharpoons \mathbf{OH}^-_{(aq)} + \text{H}_3\text{O}^+_{(aq)}$$

We know that the equilibrium for this reaction lies far to the left, as K_w is 1.0×10^{-14} . This means that **OH**⁻ is a stronger base than H₂O. OH⁻ and H₂O compete for H⁺ ions, and OH⁻ wins most of the time. This drives the equilibrium to the left.

d.
$$HF_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + \mathbf{F}^-_{(aq)}$$

F is the stronger base. HF is a weak acid, and weak acids have strong conjugate bases. We also know that F is a relatively strong base, because it is very electronegative. Water has only moderate strength as a base, as it can act as an acid or a base.

3) What is the strongest acid in each of the following reactions? Provide justification based on solution equilibrium

a.
$$\mathbf{HI}_{(aq)} + H_2O_{(1)} \rightarrow I_{(aq)}^+ + H_3O_{(aq)}^+$$

b.
$$H_2SO_{4(aq)} + H_2O_{(1)} \rightarrow HSO_{4(aq)} + H_3O_{(aq)}^+$$

c.
$$HNO_{3(aq)} + H_2O_{(l)} \rightarrow NO_{3(aq)} + H_3O^{+}_{(aq)}$$

HI, H_2SO_4 , and HNO_3 are all very strong acids. They are three of the 'Big Six' strong acids. As they experience ~100% dissociation, the equilibrium for these reactions lies very far to the right.

4) Identify the conjugate acid base pairs in the following reactions.

a.
$$HF_{(aq)} + H_2O_{(1)} \rightleftharpoons H_3O^+_{(aq)} + F^-_{(aq)}$$

Acid Base Conjugate Conjugate
Acid Base

HF and F are a conjugate acid base pair.

H₂O and H₃O⁺ are a conjugate acid base pair.

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b.
$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$$
Acid Base Conjugate Conjugate
Base Acid

CH₃COOH and CH₃COO $^{-}$ are a conjugate acid base pair. H₂O and H₃O $^{+}$ are a conjugate acid base pair.

c.
$$H_2SO_{4(aq)} + H_2O_{(1)} \rightarrow HSO_{4(aq)} + H_3O^{+}_{(aq)}$$

Acid Base Conjugate Conjugate

Base Acid

 H_2SO_4 and HSO_4^- are a conjugate acid base pair. H_2O and H_3O^+ are a conjugate acid base pair.