Chemistry 12

Acid-Base Equilibrium I

IV 4-5
pg. 109-121

Name: Notes
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1. Properties of Acids & Bases
2. Definitions of Acids and Bases
3. Conjugate Acid-Base Pairs
4. Amphiprotic Substances

Properties of Acids and Bases

	Acids	Bases
tastes	1. sour	1. bitter
feels	2. burns	2. slippery
pH	3. < 7	3. > 7, < 14
reacts with	4. metals	4. oils & fats

Definitions of Acids and Bases

Arrhenius Theory of Acid and Bases (re: Science 10)

- Arrhenius acids release H^+ ions
- Arrhenius bases release OH^- ions.

Typically... (neutralization reaction)

Acid	+	Base	→	Salt	+	Water
$HCl_{(aq)}$	+	$NaOH_{(aq)}$	→	$NaCl_{(aq)}$	+	$H_2O_{(l)}$

H-OH

Brønsted-Lowry Acids and Bases (Chem 12)

A broader definition

- Brønsted-Lowry acids donates H^+ ion. ("proton")
- Brønsted-Lowry bases accepts H^+ ion.

Example 1:

$HCl_{(aq)} + H_2O_{(l)} \rightarrow Cl^-_{(aq)} + H_3O^+_{(aq)}$

A B

Called: Hydronium Ion

$H_2O + H^+ \rightarrow H_3O^+$

HCl donates a proton, H^+, to the water molecule – HCl is acting as a B-L acid.

H_2O accepts a proton, H^+, from HCl – water is acting as a B-L base.

Example 2:

$NH_{3\,(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

B A A B

(Forward Rxn:)

NH_3 accepts a proton, H^+. NH_3 is acting as a B-L base.

H_2O donates a proton, H^+. water is acting as a B-L acid.

In the reverse reaction....

NH_4^+ donates a proton, H^+ and is acting as a B-L acid.

OH^- accepts a proton, H^+. and is acting as a B-L base.

Gain or lose?

H^+

ACID

Losing / Donating H^+

H_3A triprotic — H_2A^- diprotic — HA^{2-} Monoprotic — A^{3-}

Gaining / Accepting H^+

BASE

Rewrite the following compounds in order of decreasing number of protons:

1 3 2 0

a) HPO_4^{2-} | H_3PO_4 | $H_2PO_4^-$ | PO_4^{3-}

Acid — Base

H_3PO_4, $H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}

b) H_2O | H_3O^+ | OH^-

Acid — Base

H_3O^+, H_2O, OH^-

c) SO_4^{2-} | H_2SO_4 | HSO_4^-

Acid — Base

H_2SO_4, HSO_4^-, SO_4^{2-}

d) NH_3 | NH_2^- | NH_4^+

Acid — Base

NH_4^+, NH_3, NH_2^-

e) H_2SO_3 | SO_3^{2-} | HSO_3^-

Acid — Base

H_2SO_3, HSO_3^-, SO_3^{2-}

Practice! Identify the following as an acid or base

$HClO_4 + H_2O \rightarrow ClO_4^- + H_3O^+$
A B

$HI + H_2O \rightarrow I^- + H_3O^+$
A B

$HBr + H_2O \rightarrow Br^- + H_3O^+$
A B

$HCl + H_2O \rightarrow Cl^- + H_3O^+$
A B

$HIO_3 + H_2O \leftrightharpoons IO_3^- + H_3O^+$
A B B A

$HCOOH + H_2O \leftrightharpoons COOH^- + H_3O^+$
A B B A

$HIO_3 + OH^- \leftrightharpoons IO_3^- + H_2O$
A B B A

$H_3PO_4 + OH^- \leftrightharpoons H_2PO_4^- + H_3O^+$
A B B A

$HC_2O_4^- + H_3O^+ \leftrightharpoons H_2C_2O_4 + H_2O$
B A A B

$SO_3^{2-} + H_3O^+ \leftrightharpoons HSO_3^- + H_2O$
B A A B

Hebden Workbook Pg. 117 #11, 12
Brønsted-Lowry Acid-Base Worksheet #1-8

Day 1

Conjugate Acid-Base Pairs

Example 3 – Identify the Brønsted-Lowry acid and base in the following reaction:

$HF_{(aq)} + CN^-_{(aq)} \leftrightharpoons HCN_{(aq)} + F^-_{(aq)}$
A B A B

Two substances that differ by one H^+ ion are called a conjugate acid-base pair.

Let's practice!

HNO_3 A	+	Cl^- B	⇔	HCl A	+	NO_3^- B
PO_3^{-3} B	+	H_2O A	⇔	HPO_3^{-2} A	+	OH^- B
CN^- B	+	H_3O^+ A	⇔	HCN A	+	H_2O B
BO_2^{-3} B	+	$HC_2O_4^-$ A	⇔	HBO_2^{-2} A	+	$C_2O_4^{-2}$ B
NO_2^- B	+	PH_3 A	⇔	PH_2^- B	+	HNO_2 A
HCO_2^- B	+	NH_4^+ A	⇔	$HCOOH$ A	+	NH_3 B

Complete the following table:

has one more H+ | has one fewer H+

Conjugate Acid (donates a proton)	**Conjugate Base** (accepts a proton)
$H_2C_2O_4$	$HC_2O_4^-$
HSO_3^-	SO_3^{2-}
HCO_3^-	CO_3^{2-}
H_2O_2	HO_2^-
H_3BO_3	$H_2BO_3^-$
HCOOH	$COOH^-$
$C_6H_6O_7^-$	$C_6H_5O_7^{2-}$
H_3O^+	H_2O
H_2O	OH^-

Hebden Workbook pg. 119 #13

13. Identify each species in the following equations as being an acid or base.

a) $HF + SO_3^{2-} \rightleftharpoons F^- + HSO_3^-$

b) $H_2O + HCO_3^- \rightleftharpoons H_3O^+ + CO_3^{2-}$

c) $NO_2^- + H_2O \rightleftharpoons OH^- + HNO_2$

d) $H_2PO_4^- + S^{2-} \rightleftharpoons HS^- + HPO_4^{2-}$

e) $N_2H_5^+ + SO_4^{2-} \rightleftharpoons N_2H_4 + HSO_4^-$

Amphiprotic Substances

Substances that can act as an acid and a base

Consider the two reactions below:

$NH_3\ (aq) + H_2O\ (l) \rightleftharpoons NH_4^+\ (aq) + OH^-\ (aq)$

B A A B

$HF\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + F^-\ (aq)$

A B A B

Generally, if a substance has:
1. A negative charge and
2. An easily removable H

Then it is amphiprotic

ex. $H_2C_6H_5O_7^-$ (not easily removable; H_2 easily removable (at the end))

In the first reaction, water acts as a BL-acid. In the second reaction, water acts as a BL-base.

An amphiprotic substance has the ability to act as an acid or a base, depending on what it is reacting with.

1. Which of the following would be expected to exhibit amphiprotic behavior. Circle those that apply.

S^{2-} HSe^- H_2Se H_3PO_4 HPO_4^{2-} HSO_3^-

2. Of the species that were circled in the above question, write two equations: (1) behaving as an acid with water (2) behaving as a base with water

$HSe^- + H_2O \rightleftharpoons Se^{2-} + H_3O^+$ (A)

$HSe^- + H_2O \rightleftharpoons H_2Se + OH^-$ (B)

$HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+$ (A)

$HPO_4^{2-} + H_2O \rightleftharpoons H_2PO_4^- + OH^-$ (B)

$HSO_3^- + H_2O \rightleftharpoons SO_3^{2-} + H_3O^+$ (A)

$HSO_3^- + H_2O \rightleftharpoons H_2SO_3 + OH^-$ (B)

Complete Brønsted-Lowry Acid-Base Worksheet #9-14