Chapter 10
Acids and Bases

Most fundamental thing to remember about this chapter: Acids and Bases are opposites.

1

Acids- the Arrhenius definition

Arrhenius acid- substance that *dissociates* in water to yield hydrogen ions (protons- H^+)

2

Acids Dissociate in Solution

Dissociate- acids and bases break apart into ions when placed in water.

Previously: $CaCl_2 \rightarrow Ca^{2+} + 2\,Cl^-$

$HCl + H_2O \rightarrow H_2O + H^+ + Cl^-$ Eqn. I

$HCl + H_2O \rightarrow H_3O^+ + Cl^-$ Eqn. II

Eqn I and Eqn II mean the same thing

3

A Little More Complicated Dissociation

4

Properties of Acids

	Acid
Formula	HX
Taste	Sour
Touch	-----
Litmus	Blue → Red

5

Bases - the Arrhenius Definition

Arrhenius base- substance that dissociates in water to yield hydroxide ions (OH^-)

6

Bases Dissociate in Solution

$NaOH + H_2O \rightarrow H_2O + Na^+ + OH^-$

$Ca(OH)_2 + H_2O \rightarrow H_2O + Ca^{2+} + 2\ OH^-$

$Al(OH)_3 + H_2O \rightarrow H_2O + Al^{3+} + 3\ OH^-$

7

Properties of Bases

	Base
Formula	XOH
Taste	Bitter
Touch	Slippery
Litmus	Red → Blue

8

Demonstration

Ammonia (NH_3) Turns Litmus Paper Blue

9

Bronsted-Lowry Acids and Bases

Bronsted-Lowry acid- a proton donor
Bronsted-Lowry base- a proton acceptor

10

Nomenclature of Bases and Acids

Bases

- X OH Element hydroxide
- NH_3 Ammonia

Acids

- no oxygen hydro + Element root + ic acid
- contains oxygen
  - identify polyatomic ion
  - change -ate to -ic or -ite to -ous
  - add acid

11

Sample Test Questions

Give the name or formula of the following acids and bases

- ammonia
- $Al(OH)_3$
- carbonic acid
- HNO_3

12

Equilibrium Constant, Keq

$$aA + bB \rightleftharpoons cC + dD$$

$$Keq = \frac{[Products]}{[Reactants]} = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Keq big, →

Keq small, ←

13

Acid Ionization Constant, Ka

$$CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$$

$$Keq = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH][H_2O]}$$

$$Keq[H_2O] = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]} = Ka$$

14

Strong Acids/Weak Acids

How strong an acid is depends on how much it dissociates.

Weak acid- acetic acid, CH_3COOH

$$CH_3COOH + H_2O \rightarrow CH_3COO^- + H_3O^+$$

Ka= 1.82×10^{-5} (small)

Strong acid- HCl, H_2SO_4, HNO_3

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

Ka= infinity (big)

The Ka is a constant which you would be given

15

Sample Test Questions

- The Ka for citric acid is 8.7×10^{-4}. Is citric acid a strong acid or a weak acid?
- The Ka for HNO_3 is infinity. Is HNO_3 a strong acid or a weak acid?

16

Base Ionization Constant, Kb

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

$$Keq = \frac{[NH_4^+][OH^-]}{[NH_3][H_2O]}$$

$$Keq[H_2O] = \frac{[NH_4^+][OH^-]}{[NH_3]} = Kb$$

The Kb is a constant which you would be given

17

Sample Test Questions

- The Kb for H_2O is 1.0×10^{-7}. Is H_2O a strong base or a weak base?

18

Reactions of Acids

1. Neutralization reactions.

19

All Neutralization Reactions are Similar

$HCl + NaOH \rightarrow H_2O + NaCl$ (a salt)

$HNO_3 + NaOH \rightarrow H_2O + NaNO_3$ (a salt)

$HCl + KOH \rightarrow H_2O + KCl$ (a salt)

General Equation:

acid + base $\rightarrow H_2O$ + a salt

20

Conjugate Acid/Conjugate Base

Acid + Base $\rightarrow$ Conjugate Base + Conjugate Acid

$CH_3COOH + NH_3 \rightarrow CH_3COO^- + NH_4^+$

Conjugate Acid- the acid that is formed when a base accepts a proton.

Conjugate Base- the base that is formed when an acid donates a proton.

conjugate acid-base pairs differ only by a H^+

If acid is strong, conjugate base is weak

If base is strong, conjugate acid is weak

21

Acid-Base Titrations

- Preformed in lab
- Equation to use (Va)(Na)=(Vb)(Nb)

1. How many mL of 0.109 M HCl would be required to neutralize 25.00 mL of 0.2001 M NaOH?
2. 25.00 mL of HCl of an unknown strength required 7.69 mL of 0.1956 N KOH to get to the equivalence point. What concentration is the HCl?

22

Reactions of Acids

1. Neutralization reactions.
2. Reaction with metals

hydrogen gas produced: e.g.,

$2\ HCl + Zn \rightarrow H_2 + ZnCl_2$

23

Reactions of Acids

3. Reaction with metal carbonates and bicarbonates

CO_2 gas produced: e.g.,

$NaHCO_3 + HCl \rightarrow NaCl + H_2CO_3$

$H_2CO_3 \rightarrow H_2O + CO_2$

24

Reactions of Acids

1. Neutralization reactions.
2. Reaction with metals

   hydrogen gas produced: e.g.,

   $2\ HCl + Zn \rightarrow H_2 + ZnCl_2$
3. Reaction with metal carbonates and bicarbonates

   CO_2 produced: e.g.,

   $NaHCO_3 + HCl \rightarrow NaCl + H_2CO_3$

   $H_2CO_3 \rightarrow H_2O + CO_2$
4. Reaction with ammonia: ammonium produced

26

Ionization of Water

$$H_2O \rightleftharpoons H^+ + OH^-$$

$$Keq = \frac{[H^+][OH^-]}{[H_2O]}$$

$[H^+] = [OH^-] = 1.0 \times 10^{-7}$ M (experimentally)

$Keq\ [H_2O] = [H^+][OH^-]$

$Kw = 1.0 \times 10^{-14}$

27

pH Scale

scale of 0-14

low pH (pH 0 - pH 6) is acidic

pH 7 is neutral

high pH (pH 8 - pH 14) is basic

$pH = -\log [H_3O^+]$

Because log scale, a difference of 1 pH unit means there are 10× as many protons.

28

pH Math

$pH = -\log [H_3O^+]$

$pOH = -\log [OH^-]$

$[H_3O^+]\,[OH^-] = 1.0\times10^{-14}$

$pH + pOH = 14$

29

Sample Test Questions

- What is the pH of a solution containing 1.0×10^{-6} M HCl?
- What is the pH of a solution containing 1.0×10^{-6} M NaOH?
- How many more protons are in a solution of pH 4.0 than one of pH 6.0?
- How many more protons are in a solution of pH 4.0 than one of pH 4.3?

30

Sample Test Questions

- What is the $[H_3O^+]$ in blood at pH 7.40?
- What is the pH of a solution containing 0.365 g hydrochloric acid in 500.0 mL water?
- What is the pH of a solution containing 9.25 g sodium hydroxide in 250.0 mL water?

31

pH of Salt Solutions

Acid + base → water + salt

$HCl + NaOH \rightarrow NaCl + H_2O$

strong acid, strong base: neutral solutions.

$HCl + NH_3 \rightarrow NH_4Cl$

Strong acid, weak base: acidic

$H_2CO_3 + 2\ NaOH \rightarrow 2\ H_2O + Na_2CO_3$

Weak acid, strong base: basic

Weak acid, weak base: can't predict easily

32

Buffers

Buffer- a compound that does not allow the pH to change even if acid or base is added to the system.

Must have a weak acid and its salt. Good buffers are often *amphiprotic* compounds.

Amphiprotic compound- a compound that can act as a proton donor or as a proton acceptor.

33

Buffers

Why do buffers have to be a weak acid and salt of weak acid?

Compounds are good buffers at pH = ±0.5 pKa (because within this range they exist as weak acid and salt of weak acid).

34

Sample Test Questions

The pKa of oxalic acid is 4.3. In what pH range would oxalic acid be a good buffer?

The Ka_1 of H_3PO_4 is 7.107×10^{-3}. What is the pKa_1 of H_3PO_4?

The Ka_2 of citric acid is 1.73×10^{-5}. In what pH range would citric acid be a good buffer?

35

pH with Buffers: the Henderson-Hasselbalch Equation

$$pH = pKa + \log \frac{[salt]}{[acid]}$$

$$pH = pKa + \log \frac{[A^-]}{[HA]}$$

36

Sample Test Questions

If I mix 50.0 mL of 1.6 M NaH_2PO_4 with 25.0 mL of 1.6 M Na_2HPO_4, what would the pH of the mixture be? The pKa is 7.21.

$$pH = pKa + \log \frac{[A^-]}{[HA]}$$
$$= 7.21 + \log \frac{[0.53\,M]}{[1.07\,M]}$$
$$= 7.21 + \log 0.5$$
$$= 7.21 + (-0.30)$$
$$pH = 6.91$$

37

Sample Test Questions

If I mix 10.0 mL of 1.0 M CH_3COOH with 10.0 mL of 1.0 M CH_3COO^-, what would the pH of the mixture be? The Ka of CH_3COOH is 1.8×10^{-5}.

If I mix 20.0 mL of the above buffer with with 1.2 mL 1.0 M NaOH, what would the pH of the mixture be?

38

Buffers in Lab

Solution 6:10 mL 1 M NH_4OH, 10 mL 1 M NH_4^+

Solution 6

$$pH = pKa + \log\frac{[A^-]}{[HA]}$$

$$= 9.23 + \log\frac{[\frac{(10\text{ mL } NH_4OH)(1\text{ M})}{20\text{ mL}}]}{[\frac{(10\text{ mL } NH_4Cl)(1\text{ M})}{20\text{ mL}}]}$$

$$= 9.23 + \log 1$$

$$= 9.23 + (0)$$

$$pH = 9.23$$

Solution 7

$$pH = pKa + \log\frac{[A^-]}{[HA]}$$

$$= 9.23 + \log\frac{[5]}{[20]}$$

$$= 9.23 + \log 0.25$$

$$= 9.23 + (-0.60)$$

$$pH = 8.63$$

Solution 7: 5 mL 1 M NH_4OH, 20 mL 1 M NH_4^+

39

Summary of Acids and Bases

	Acid	Base
Arrhenius dfn	ionizes to H^+	ionizes to OH^-
B-L dfn	proton donor	proton acceptor
Formula	HX	XOH
Taste	Sour	Bitter
Touch	-----	Slippery
Litmus	Blue → Red	Red → Blue
pH	<7	>7
Reactions	Neutralizes Base	Neutralizes Acid