Dr Kepert, Chem 1101

Acids and Bases I

Silberberg 2nd Ed, Chapter 18 & 19

www.chem.usyd.edu.au/hpage3.htm (login “chem”, passwd “chem@usyd”)
http://www.science.ubc.ca/~chem/tutorials/pH/launch.html
Any questions or requests - email to ch1101a@chem.usyd.edu.au

QUIZ 3

To be handed in by 5pm, Tuesday 22nd May
- multichoice sheets to be picked up as before
- submit sheets into slot as before

If there are questions you can’t answer:
- come and ask me in tutes or after lectures

Equilibria In Acids & Bases

In water: an acid (e.g., HCl) ionises to produce H⁺ (aq)
- actually H₃O⁺ (aq), but we usually just write H⁺ (aq)

Definitions

• Arrhenius: H⁺ + OH⁻ ⇔ H₂O
  – ACID: H⁺
  – BASE: OH⁻

• Brønsted - Lowry: H⁺ + A⁻ ⇔ HA
  – ACID: H⁺
  – BASE: A⁻

• Lewis: A + :B ⇔ A:B
  – ACID: A
  – BASE: :B

Conjugate Acid-base Pairs

• NH₄⁺ is the conjugate acid of NH₃
• NH₃ is the conjugate base of NH₄⁺

A conjugate base has one less proton than its conjugate acid

• HSO₄⁻: conjugate base is SO₄²⁻
  conjugate acid is H₂SO₄
• H₂SO₄ is dibasic or diprotic acid:

  H₂SO₄ + H₂O ⇔ H₃O⁺ + SO₄²⁻
  HSO₄⁻ + H₂O ⇔ H₂O⁺ + SO₄²⁻

(lies ~100% to right)

Examples

Write the formula of the conjugate bases
Write the formula of the conjugate acids

H₃O⁺ OH⁻
H₂SO₄ H₂O
HClO₄ CN⁻
CH₃COOH NH₃
HPO₄²⁻ HPO₄²⁻

Acid-Base Reactions (see Silberberg)

Table 18.4 The Conjugate Pairs in Some Acid-Base Reactions

<table>
<thead>
<tr>
<th>Acid</th>
<th>Base</th>
<th>Base</th>
<th>Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>H⁺</td>
<td>H₂O</td>
<td>H⁺</td>
<td>H₂O</td>
</tr>
<tr>
<td>H⁺</td>
<td>CN⁻</td>
<td>H⁺</td>
<td>CN⁻</td>
</tr>
<tr>
<td>NH₄⁺</td>
<td>CO₃²⁻</td>
<td>NH₄⁺</td>
<td>CO₃²⁻</td>
</tr>
<tr>
<td>H⁺</td>
<td>PO₄³⁻</td>
<td>H⁺</td>
<td>PO₄³⁻</td>
</tr>
<tr>
<td>H⁺</td>
<td>S₂O₃²⁻</td>
<td>H⁺</td>
<td>S₂O₃²⁻</td>
</tr>
<tr>
<td>H⁺</td>
<td>SO₄³⁻</td>
<td>H⁺</td>
<td>SO₄³⁻</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Acid</th>
<th>Base</th>
<th>Base</th>
<th>Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HF</td>
<td>H₂O</td>
<td>H⁺</td>
<td>H₂O</td>
</tr>
<tr>
<td>2</td>
<td>HCOOH</td>
<td>CN⁻</td>
<td>H⁺</td>
<td>CN⁻</td>
</tr>
<tr>
<td>3</td>
<td>NH₄⁺</td>
<td>CO₃²⁻</td>
<td>NH₄⁺</td>
<td>CO₃²⁻</td>
</tr>
<tr>
<td>4</td>
<td>H⁺PO₄³⁻</td>
<td>O²⁻</td>
<td>H⁺PO₄³⁻</td>
<td>H⁺</td>
</tr>
<tr>
<td>5</td>
<td>H⁺SO₄²⁻</td>
<td>N₃⁻</td>
<td>H⁺SO₄²⁻</td>
<td>N₃⁻</td>
</tr>
<tr>
<td>6</td>
<td>H⁺PO₄³⁻</td>
<td>SO₄³⁻</td>
<td>H⁺</td>
<td>SO₄³⁻</td>
</tr>
</tbody>
</table>

Tableau 18.4 The Conjugate Pairs in Some Acid-Base Reactions

Autoionisation of Water

H₂O (l) ⇔ H⁺ (aq) + OH⁻ (aq)

- Equilibrium constant given special symbol:

  K_w = [H⁺][OH⁻]

  NB: [H₂O (l)]: actually activity, which is = 1

  At 25 °C: K_w = 1.0 × 10⁻¹⁴

  Neutral solution: [H⁺] = [OH⁻] = 1.0 × 10⁻⁷ mol L⁻¹
  Acidic solution: [H⁺] > 1.0 × 10⁻⁷ M
  Basic : [H⁺] < 1.0 × 10⁻⁷ M
**Autoionisation of Water**

\[ \text{pH} = -\log_{10}[H^+] \]
\[ \text{pOH} = -\log_{10}[OH^-] \]
\[ \text{pK}_w = -\log_{10}[K_w] = 14 \text{ at } 25^\circ\text{C} \]

Acid: pH < 7
Neutral: pH = 7
Basic: pH > 7

The 'p' Convention

\[ \log_{10} K_w = \log_{10}[H^+] + \log_{10}[OH^-] \]
\[ -\log_{10}[H^+] - \log_{10}[OH^-] = -\log_{10} K_w \]
\[ \text{pH} + \text{pOH} = 14 \]
\[ \text{pOH} = 14 - \text{pH} \]

**Strong Acids & Bases**

Completely ionise in water:
- e.g. HCl $\rightleftharpoons$ $H^+$ + $Cl^-$
  - equilibrium lies completely to right, $K_w = \infty$

**Strong acids**
- $H_2SO_4$, HCl, HBr, HI, HNO$_3$, HClO$_4$

**Strong bases**
- All hydroxides of Groups 1 & 2 (except Be): NaOH, Ca(OH)$_2$, ...
- HF: NOT strong acid !!
  - because H$-$F bond stronger than O$-$H

**Examples**

- What is the pH of a 0.1 M HCl solution?
- What is the pH of a 0.002 M NaOH solution?

**More Examples**

Calculate the pH of:
0.001 M HNO$_3$
0.001 M NaOH
0.001 M Ca(OH)$_2$

What is the pH of a solution formed by mixing 400 mL of 0.05 M HCl with 600 mL of 0.05 M NaOH?

What is the pH of a solution with a pH of 4.5?

**Harder Example**

- What is the pH of a 2.0 $\times$ $10^{-7}$ M HCl solution?

**Weak Acids and Bases**

- Any acid or base not on the list of strong ones is weak - it does not completely ionise in water.
- e.g., acetic (ethanoic) acid, $CH_3CO_2H$ (HA for short):
  - HA $\rightleftharpoons$ $H^+$ + $A^-$
  - $K_a$ not infinite; given special symbol: $K_a$
  - $K_a = \frac{[H^+][A^-]}{[HA]}$
  - for acetic acid, $K_a = 10^{-4.7}$ M
  - p$K_a$ = 4.7
  - pH of 0.1 M solution of acetic acid $> 1$
  - (pH would be $-\log(0.1) = 1$ only if it were completely ionised)

**Comparing Strong and Weak Acids**