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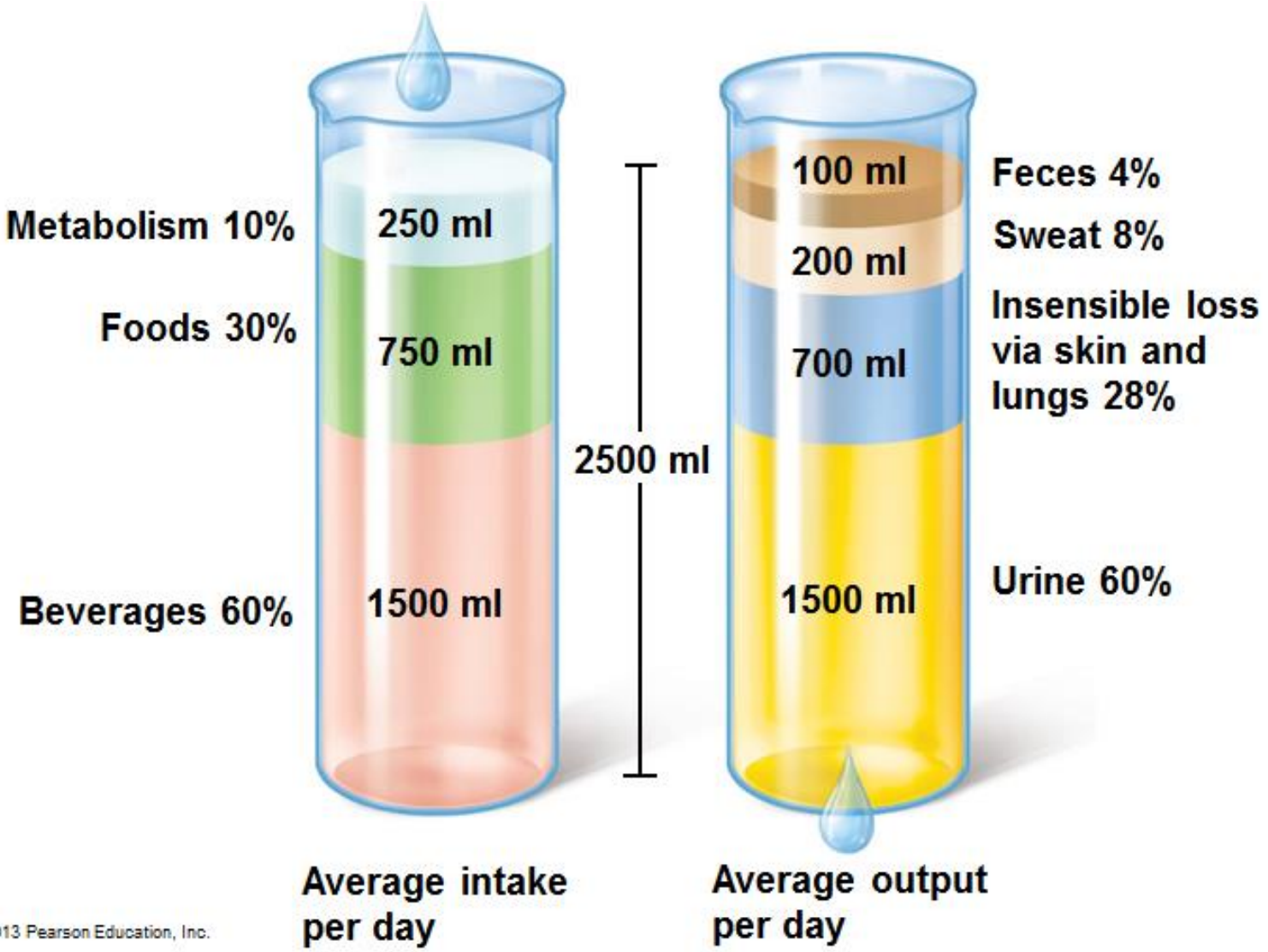
Electrolytes, pH, and Acid-Base Balance

Dr. Hadi Ansarihadipour

Clinical Biochemist, Ph.D.

Arak University of Medical Sciences



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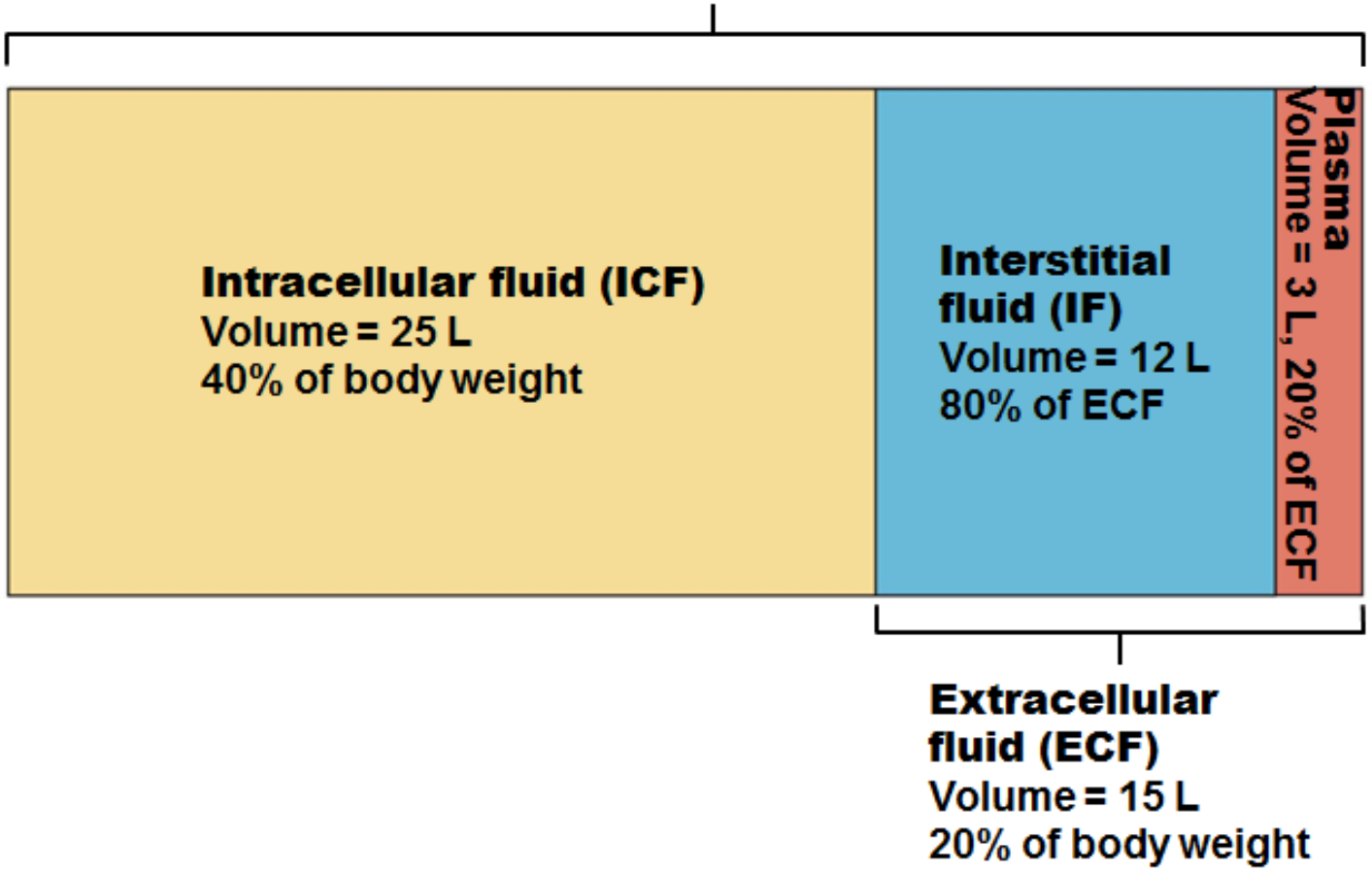
Major fluid compartments of the body



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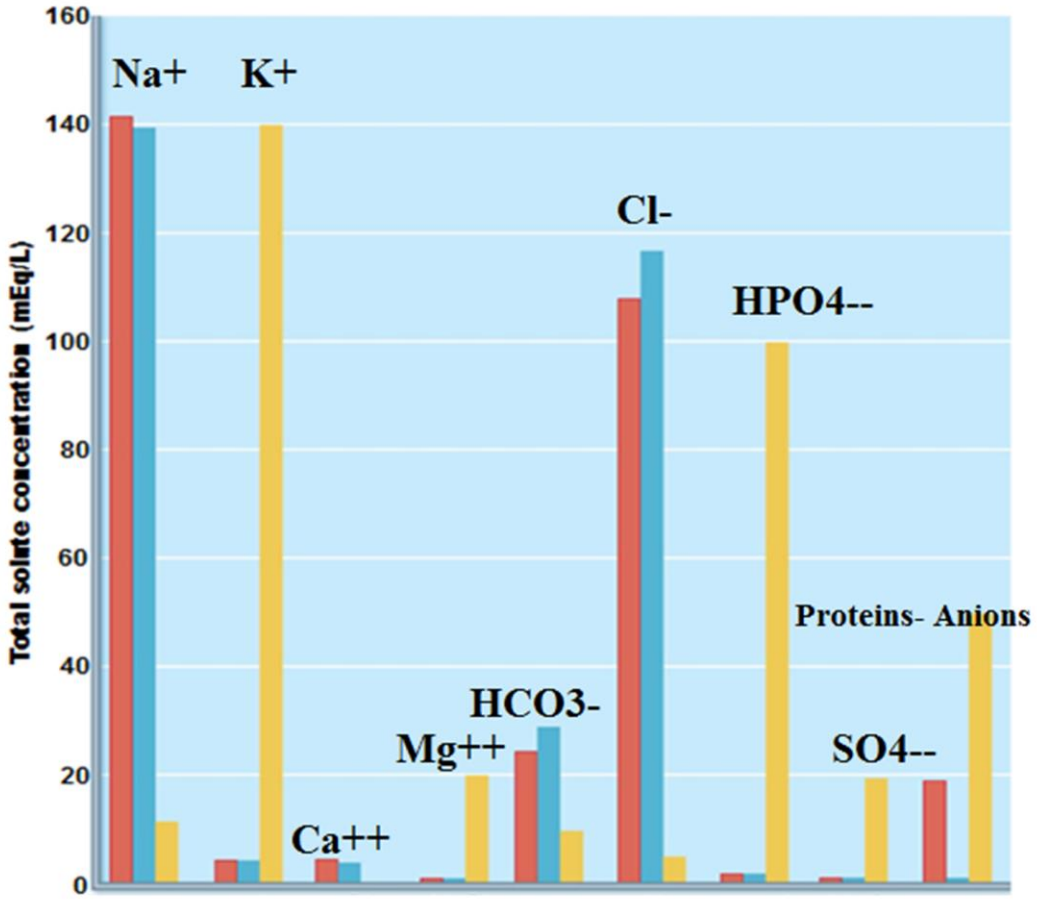
Electrolyte Composition of Plasma, Interstitial Fluid, and Intracellular Fluid

Blood plasma
Interstitial fluid
Intracellular fluid

Na^+	Sodium
K^+	Potassium
Ca^{2+}	Calcium
Mg^{2+}	Magnesium
HCO_3^-	Bicarbonate
Cl^-	Chloride
HPO_4^{2-}	Hydrogen phosphate
SO_4^{2-}	Sulfate



Normal saline = 0.9% NaCl = 9 g NaCl in 1 L

MW(NaCl)=58.5

(9 g/L)/(58.5 g/mole) = 0.15 mole/L = 150 mM/L

D5W = 5% dextrose in water = 278 mM/L

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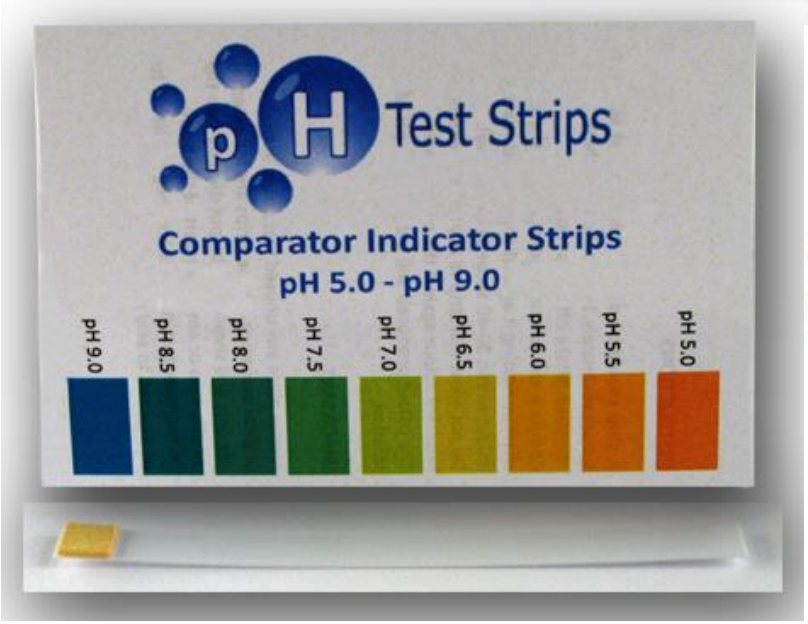
Acids and Bases

$$[H^+]$$

$$[OH^-]$$

$$pH$$

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


pH Test Strips
Comparator Indicator Strips
pH 5.0 - pH 9.0
pH 9.0
pH 8.5
pH 8.0
pH 7.5
pH 7.0
pH 6.5
pH 6.0
pH 5.5
pH 5.0


pH
1-11

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pH	Examples of solutions
0	Battery acid, strong hydrofluoric acid
1	Hydrochloric acid secreted by stomach lining
2	Lemon juice, gastric acid, vinegar
3	Grapefruit juice, orange juice, soda
4	Tomato juice, acid rain
5	Soft drinking water, black coffee
6	Urine, saliva
7	“Pure” water
8	Sea water
9	Baking soda
10	Great Salt Lake, milk of magnesia
11	Ammonia solution
12	Soapy water
13	Bleach, oven cleaner
14	Liquid drain cleaner

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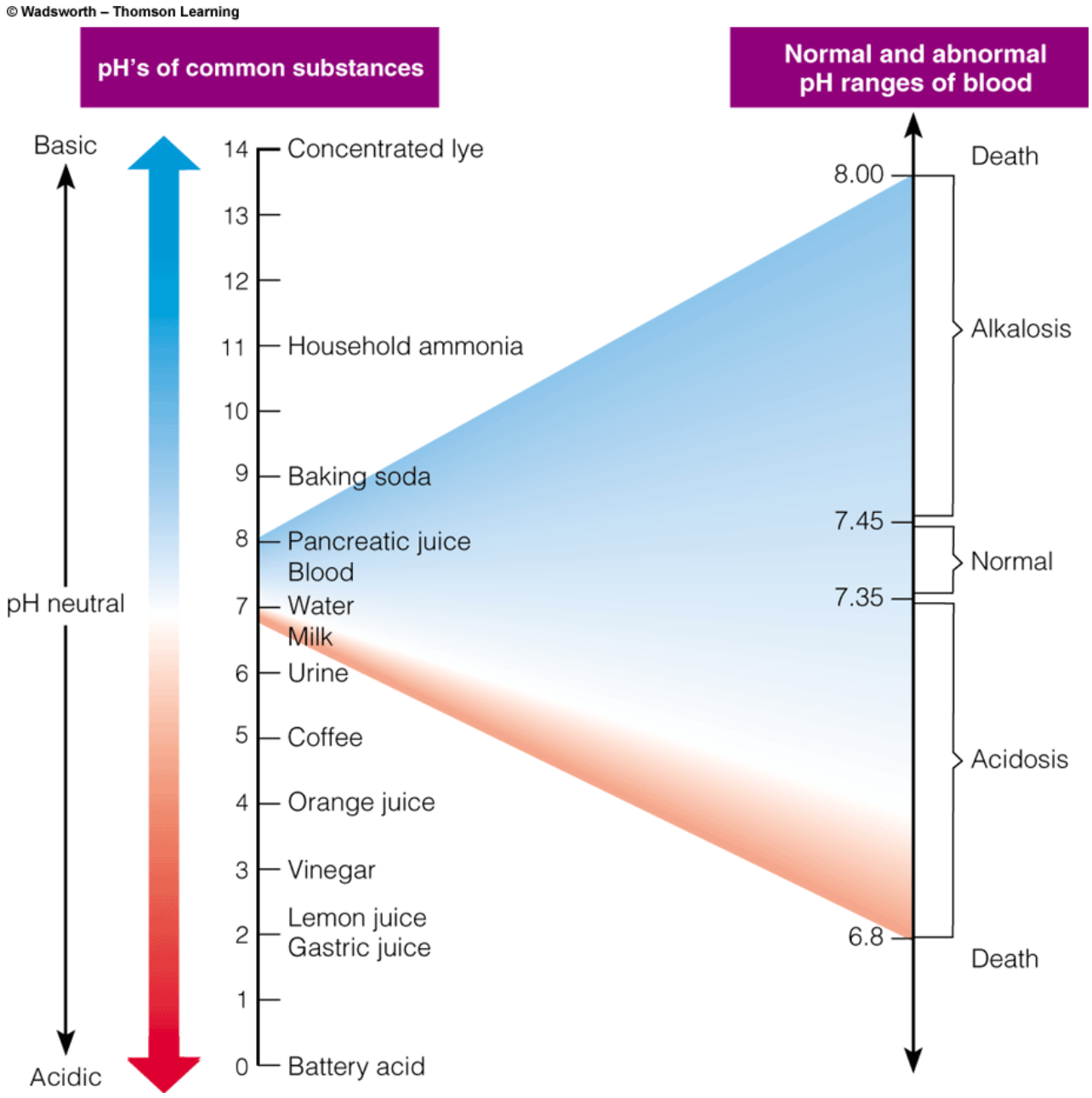

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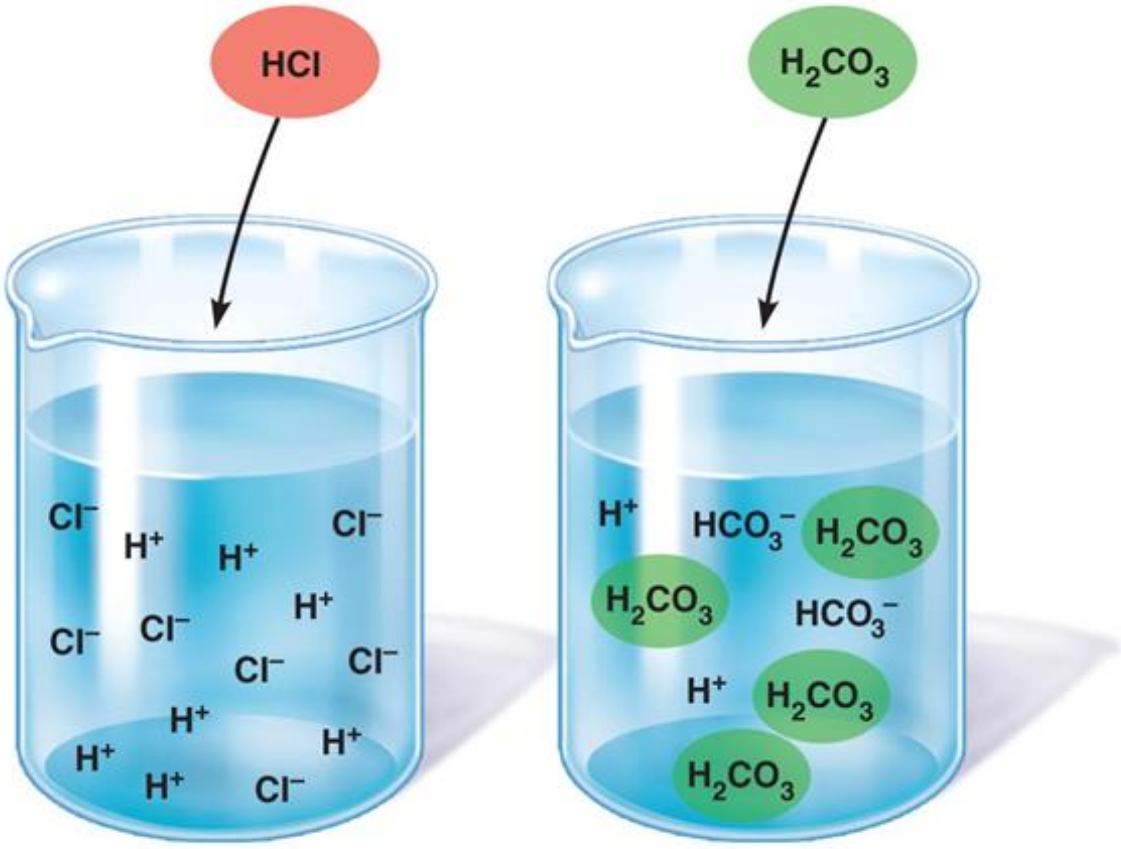
Strong Acids -Weak Acids



(a) A strong acid such as HCl dissociates completely into its ions.

(b) A weak acid such as H_2CO_3 does not dissociate completely.

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pK

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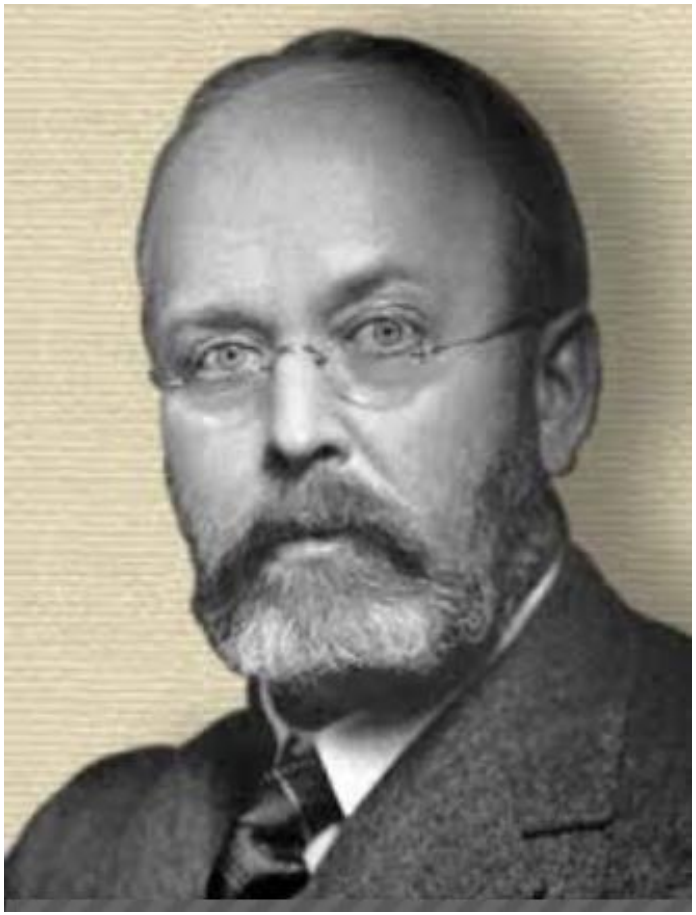
Lawrence Joseph Henderson

(June 3, 1878, Lynn, Massachusetts – February 10, 1942, Cambridge, Massachusetts) was a physiologist, chemist, biologist, philosopher, and sociologist. He became one of the leading biochemists of the early 20th century.



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Karl Albert Hasselbalch

(1 November 1874 in Aastrup, Denmark – 19 September 1962) was a physician and chemist.

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Henderson–Hasselbalch equation

$$\mathrm{pH} = \mathrm{p}K_\mathrm{a} + \log_{10}\left(\frac{[\mathrm{A}^-]}{[\mathrm{HA}]}\right)$$

سوال

در خون یک بیمار، غلظت اسید کربنیک 1.2 میلی اکی والان گرم و غلظت یون بیکربنات 24 میلی اکی والان گرم است.

1. pH خون چقدر است؟
2. آیا نیازی به درمان هست؟

Pk اسید کربنیک معادل 6.1 است.

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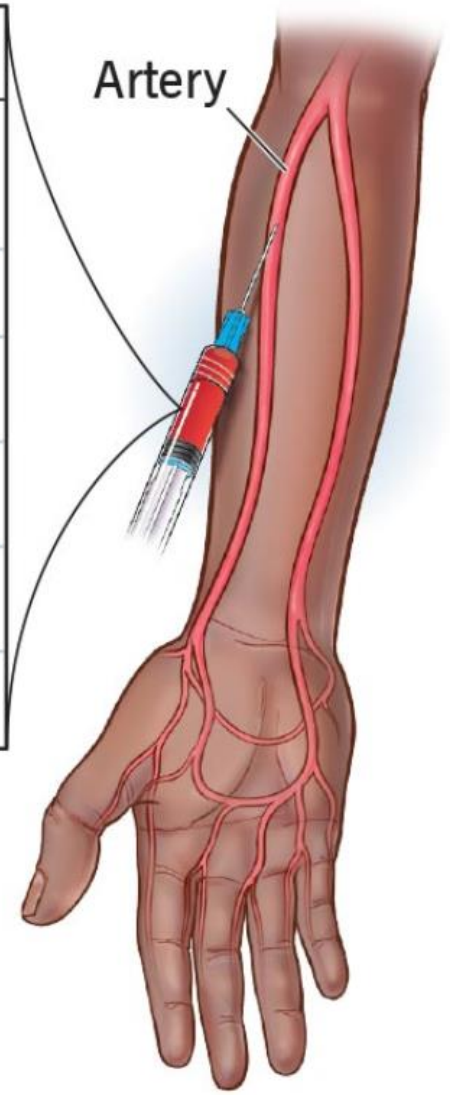
پاسخ: طبیعی

$$pH=6.1+1.3=7.4$$

Arterial Blood Gas (ABG)

ABG	Normal range
O_2CT	15-23% per 100 mL of blood
pH	7.35-7.45
$PaCO_2$	35-45 mmHg
PaO_2	80-100 mmHg
HCO_3	22-26 mEq/L
O_2Sat	95-100%



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Buffer

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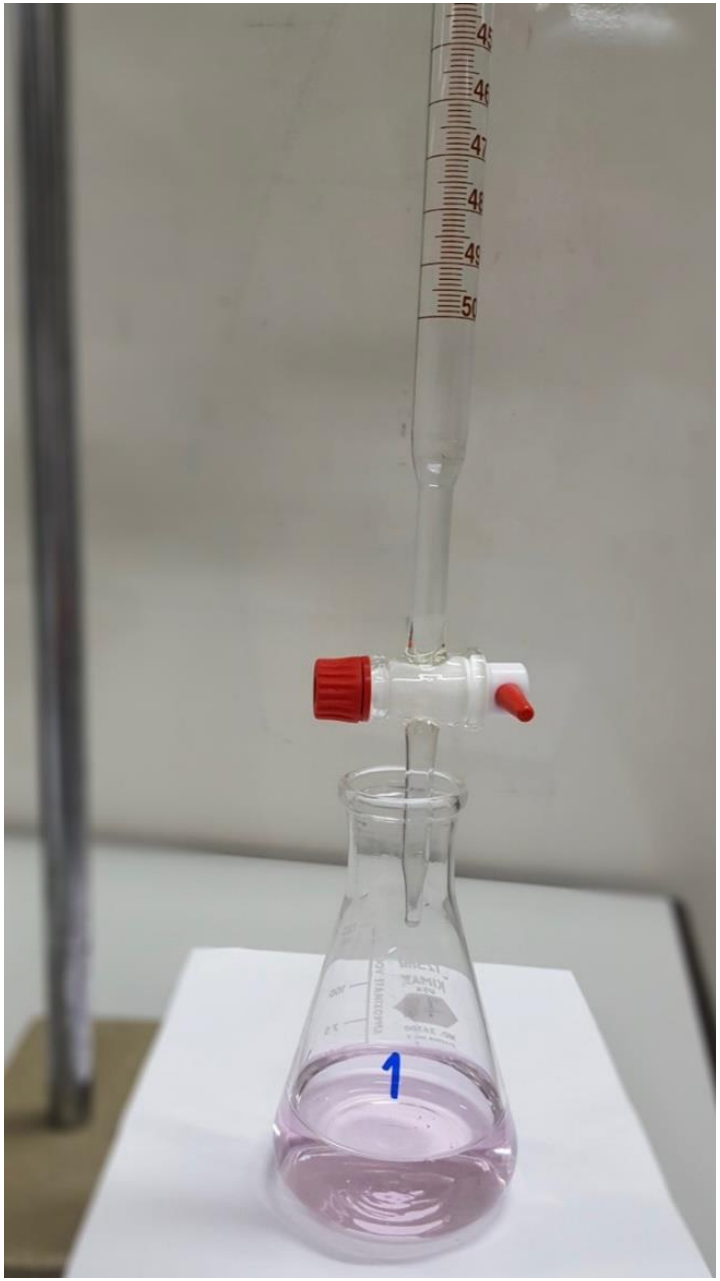
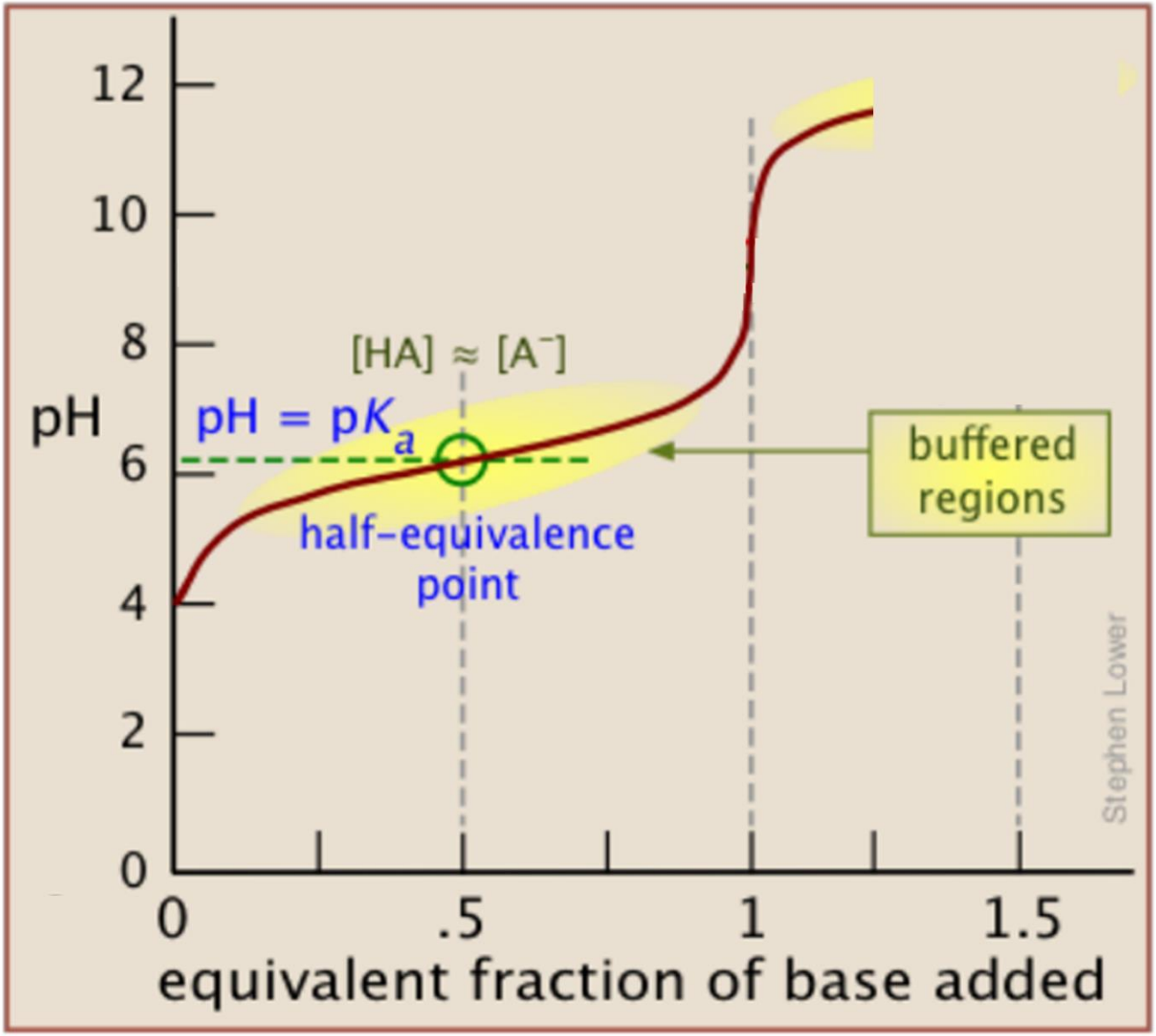
Titration




12
10
8
6
4
2
0
pH
[HA] ≈ [A⁻]
pH = pKa
half-equivalence point
buffered regions
Stephen Lower
0
.5
1
1.5
equivalent fraction of base added

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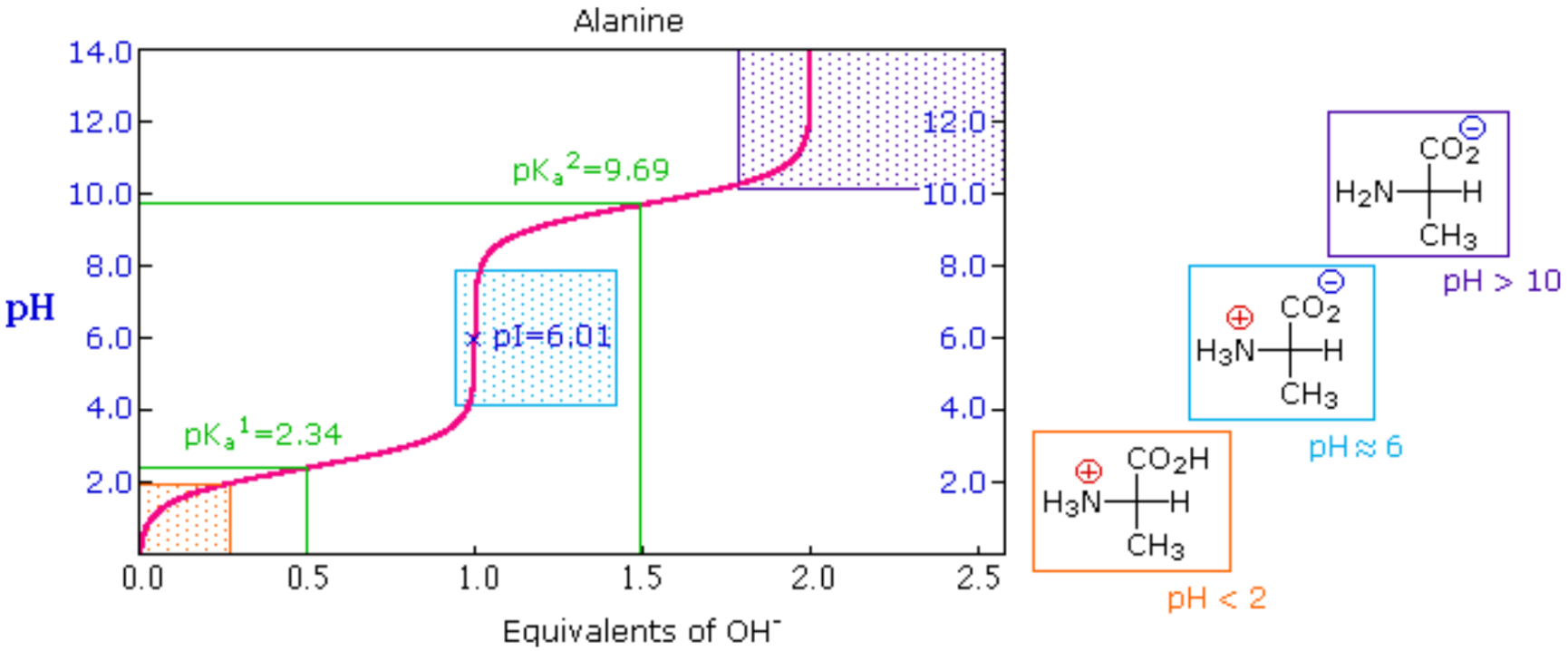
Amino acids


Alanine
pH
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.5
1.0
1.5
2.0
2.5
Equivalents of OH⁻
pKa²=9.69
pI=6.01
pKa¹=2.34
pH > 10
pH ≈ 6
pH < 2

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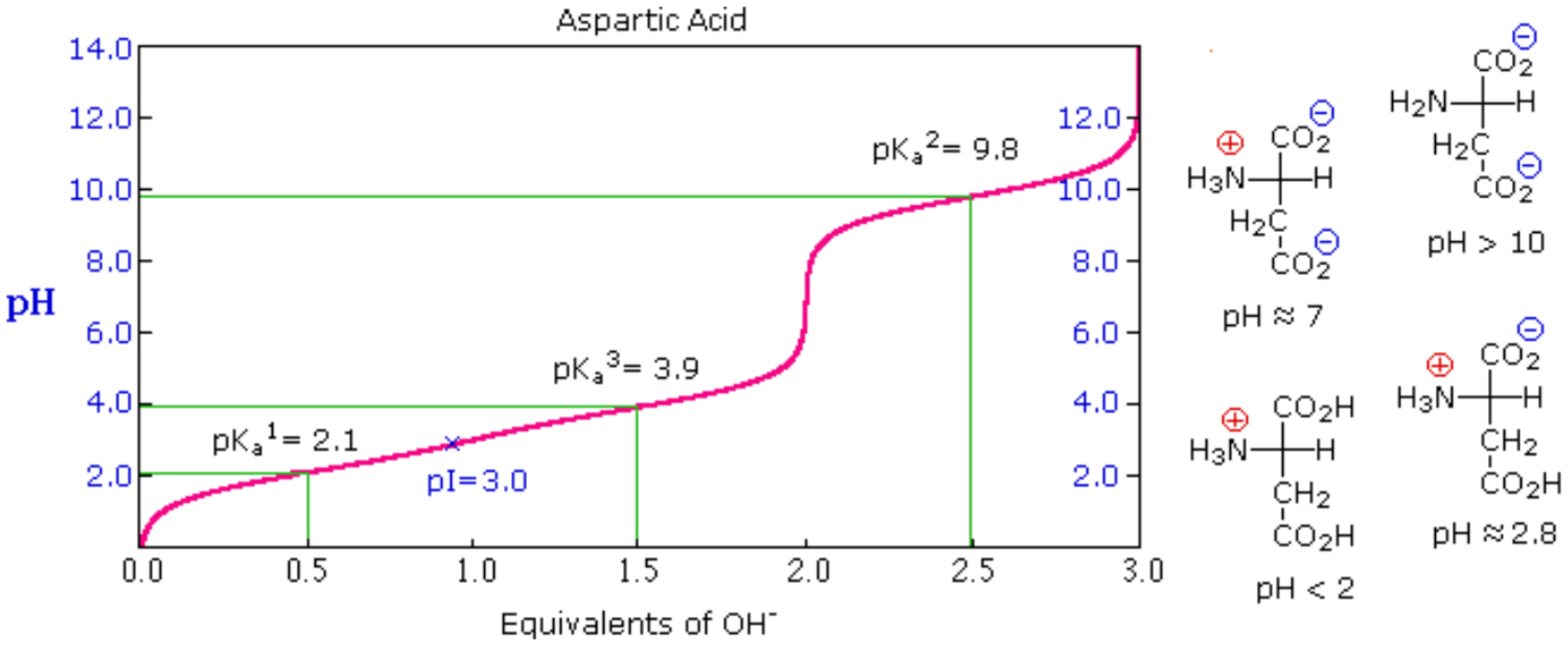
Titration of an Acidic Amino Acid



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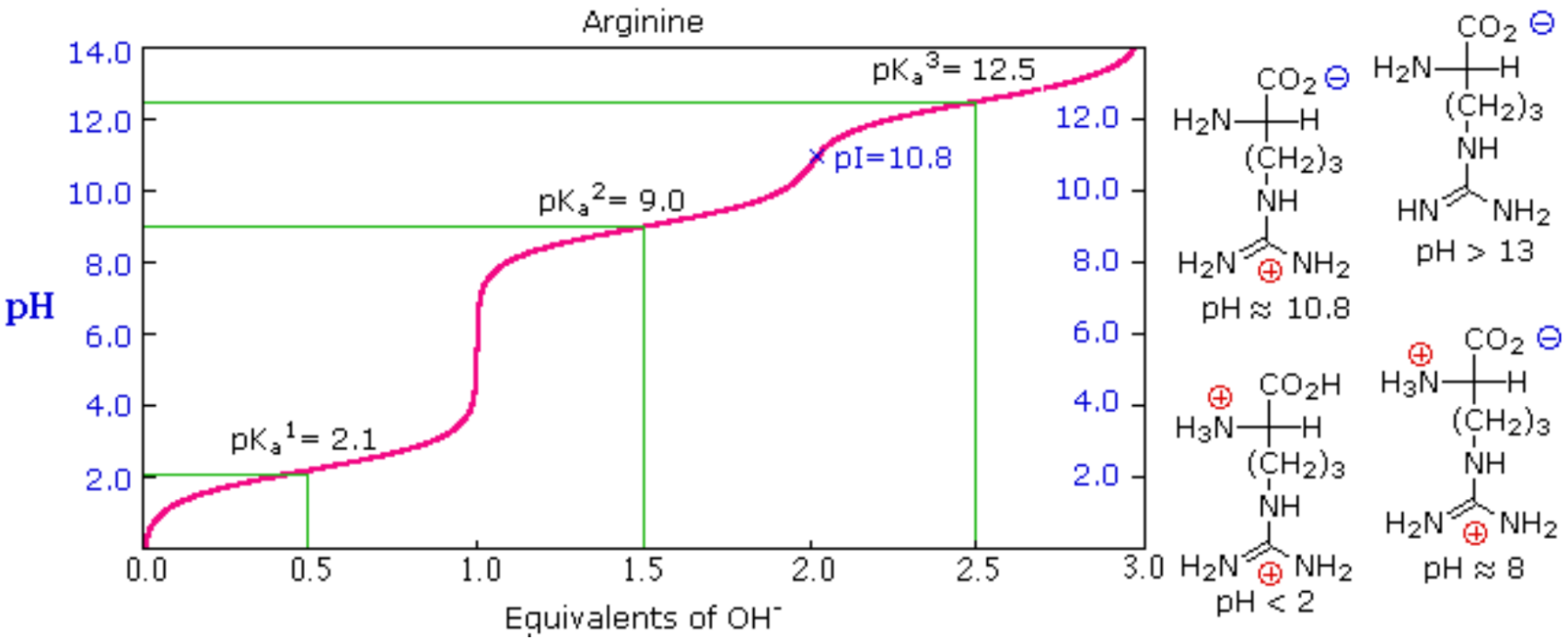
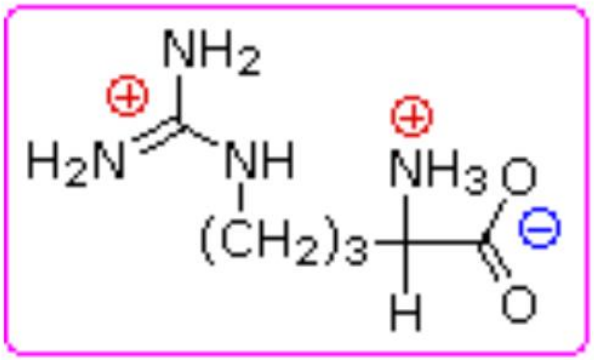
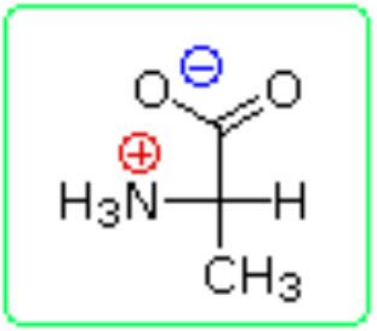
Titration of a Basic Amino Acid



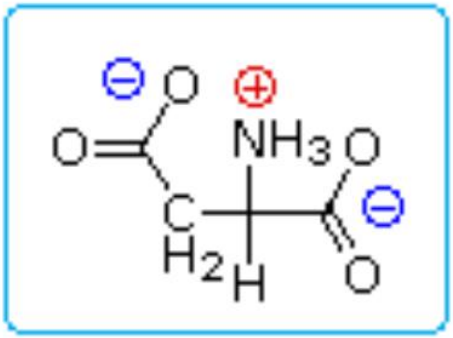
The pI of different amino acids



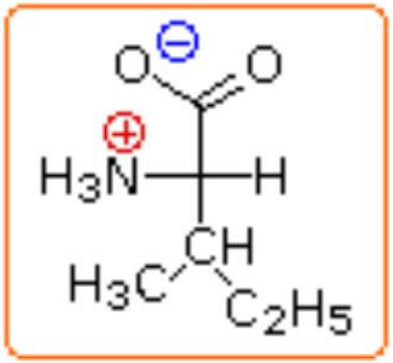
arginine pI=10.77



alanine pI=6.01



aspartic acid pI=2.80

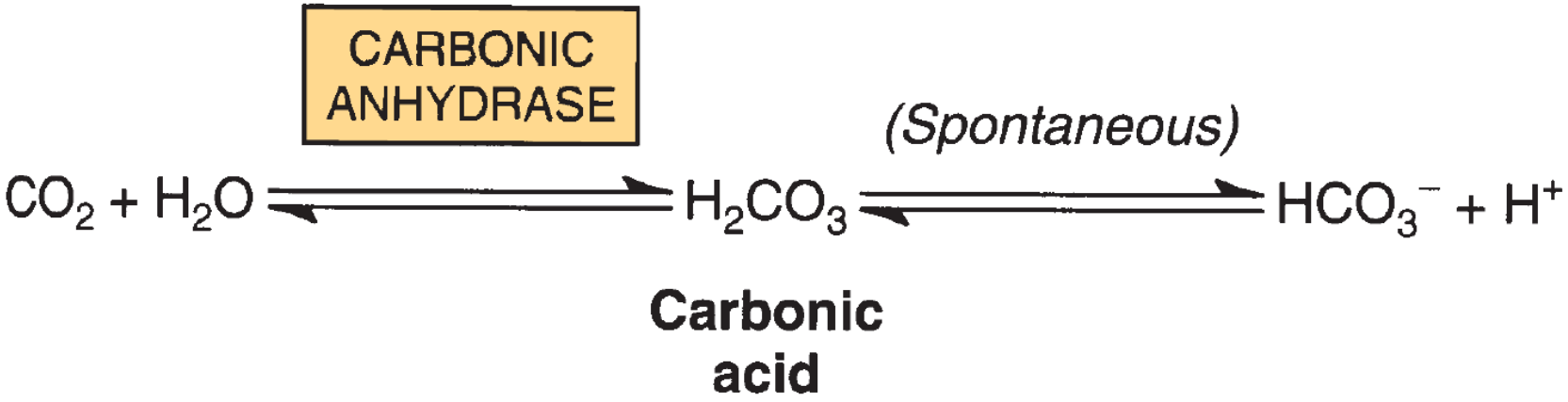


isoleucine pI=6.02

Main Biologic Buffers

1. Proteins: Albumin, Hb, Mb
2. Phosphate
3. Bicarbonate

Bicarbonate Buffer



$$pH = pK_a + \text{Log}\frac{[HCO_3^-]}{[H2CO_3]}$$

$$pH = pK_a + \text{Log}\frac{[HCO_3^-]}{[PCO_2]}$$

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سوال

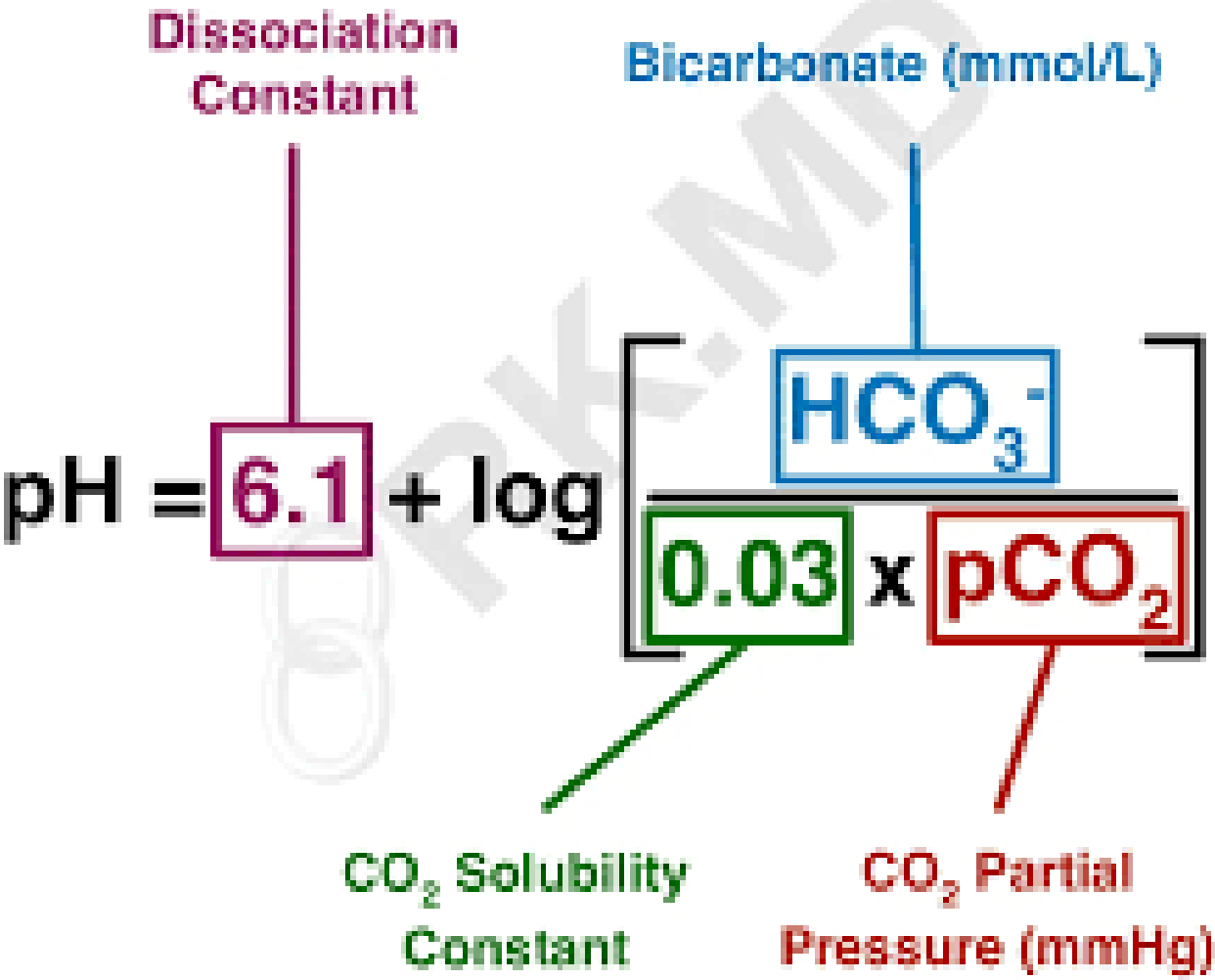
فشار گاز CO2 در خون یک بیمار 60 میلی متر جیوه و غلظت یون بیکربنات 24 میلی اکی والان گرم است.

1. pH خون چقدر است؟
2. آیا نیازی به درمان هست؟

راهنمایی

1. هر میلی متر جیوه از CO_2 معادل 0.03 میلی اکی والان گرم اسید کربنیک تولید می کند.
2. فشار CO_2 در خون 40 میلی متر جیوه است.
3. Pk اسید کربنیک معادل 6.1 است.

HENDERSON-HASSELBALCH



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پاسخ: اسیدوز تنفسی

$$pH=6.1+1.1=7.2$$

$$pH = pK_a + Log \frac{[HCO_3^-]}{[PCO_2]}$$

Respiratory Acidosis

اسیدوز تنفسی	بیماری ریوی فلج عضلات تنفسی مصرف داروی خواب آور	کلیه: بازجذب بیکربنات تولید آمونیاک

$$pH = pK_a + \text{Log}\frac{[HCO_3^-]}{[PCO_2]}$$

Respiratory Alkalosis

آلکالوز تنفسی	هیپرونتیلاسیون افزایش تهویه ریوی	کلیه: دفع بیکربنات

$$pH = pK_a + \text{Log}\frac{[HCO_3^-]}{[PCO_2]}$$

Metabolic Acidosis

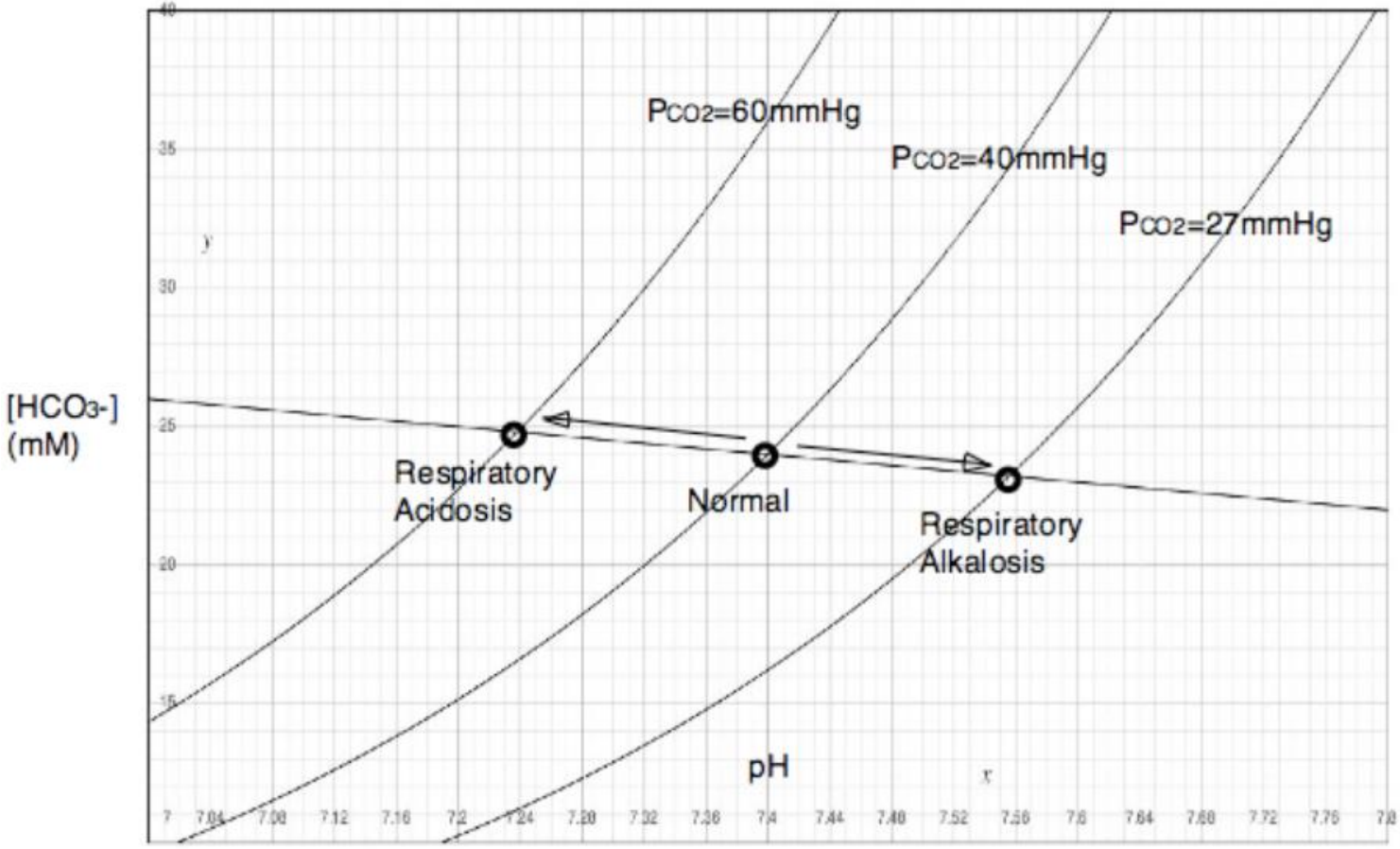
اسیدوز متابولیک	اسهال شدید کتواسیدوز اختلال کلیوی	ریه: دفع CO2 کلیه: دفع هیدروژن

$$pH = pK_a + \text{Log}\frac{[HCO_3^-]}{[PCO_2]}$$

Metabolic Alkalosis

آلکالوز متابولیک	مصرف بیکربنات سدیم استفراغ دفع اسید ها از ادرار	ریه: کاهش تنفس کلیه: دفع بیکربنات

Respiratory Acidosis and Alkalosis (Davenport Diagram)



AG or **AGAP**

Serum anion gap

$$(Na^+ + K^+) - (Cl^- + HCO_3^-)$$

AG

$$(Na^{+}) - (Cl^{-} + HCO_3^{-}) = 20\ mEq/L$$

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References:

1. Murray R.K., Granner D.K., Rodwell V.W. Harper's Illustrated Biochemistry, 30th edition. McGraw Hill, 2015.
2. Author' articles: ncbi.nlm.nih.gov
3. https://en.wikipedia.org

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