Department of Medicine
MED 442 Lectures

King Saud University
University Medical City

Approach to Common Electrolytes and Acid-Base Disorders: A Case Discussion

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A 22 year-old male was brought in to ER by his family unresponsive!

131	99	2.0	16.1
3.8	9.7	77	

1. Please interpret each component of this chemistry lab report.
2. What else you need to know? (History? Exam? Lab?)

BMP: Basic Metabolic Panel

Na^+	Cl^-	Urea	Gluc
K^+	TCO_2	Creat	

Venous vs. Arterial vs. Capillary Blood Gases

VBG: 7.24/22.5/47.6/9

VBG: pH/pCO_2/pO_2/$HCO3^-$/BE

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3. What is Henderson equation?
4. What is the difference between pCO_2 and Total CO_2 (TCO_2 or "CO_2")?
5. What is the difference between Total CO_2 and $[HCO_3^-]$?

What is Henderson equation?

$$H_2O + CO_2 \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO3^-$$

$$[H^+] = 24 \times \frac{pCO2}{[HCO3^-]}$$

40 (nmol/L) = 24 x [40 (mmHg)/24 (mmol/L)]

$$pH = pK + \log \frac{[HCO_3^-]}{[PCO_2 \times 0.03]}$$

$$= 6.1 + \log \frac{24 \text{ mEq/L}}{(40 \times 0.03)}$$

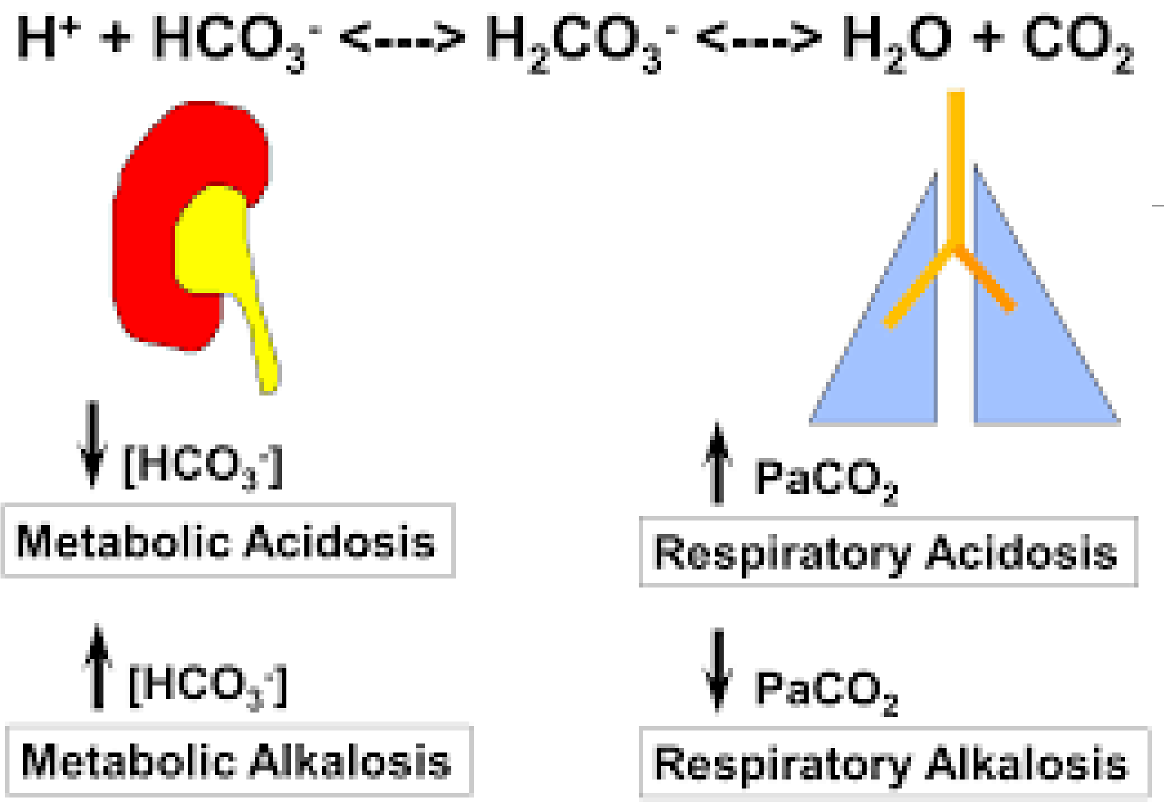
$$= 6.1 + \log \frac{24 \text{ mEq/L}}{(1.2 \text{ mEq/L})}$$

$$= 6.1 + \log \frac{20}{1} \quad (20{:}1 \text{ ratio})$$

$$= 6.1 + 1.3$$

$$= 7.4$$

https://media.lanecc.edu/users/driscolln/RT127/Softchalk/Acid_Base_Lesson/Acid_Base_Lesson5.html



Hamilton, P. K., Morgan, N. A., Connolly, G. M., & Maxwell, A. P. (2017). Understanding Acid-Base Disorders. *The Ulster medical journal*, *86*(3), 161–166.

What is Henderson equation?

$$H_2O + CO_2 \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO3^-$$

$$\text{Total } CO_2 = [CO_2] + [H_2CO_3] + [HCO3^-]$$

Venous Total CO_2 > Arterial $[HCO3^-]$ by 1.5-2 mmol/L

Internally consistent data!

Metabolic vs. Respiratory Disorders

$$H_2O + CO_2 \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO3^-$$

$$[H^+] = 24 \times \frac{pCO2}{[HCO3^-]}$$

6. Why do we have two metabolic compensations for respiratory disorders?

Metabolic vs. Respiratory Disorders

$$H_2O + CO_2 \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO3^-$$

$$[H^+] = 24 \times \frac{pCO2}{[HCO3^-]}$$

Lungs

Metabolism & Kidneys

6. Why do we have two metabolic compensations for respiratory disorders?

Acid Base Disorders

Primary disorder	Compensatory response
Metabolic acidosis	$PCO_2 = 1.5 \times (HCO_3^-) + 8 +/- 2$ [Winter's formula]
Metabolic alkalosis	0.6 mm ↑ pCO_2 per 1.0 mEq/L ↑ HCO_3^-
Acute respiratory acidosis	1 mEq/L ↑ HCO_3^- per 10 mm ↑ pCO_2
Chronic respiratory acidosis	3.5 mEq/L ↑ HCO_3^- per 10 mm ↑ pCO_2
Acute respiratory alkalosis	2 mEq/L ↓ HCO_3^- per 10 mm ↓ pCO_2
Chronic respiratory alkalosis	5 mEq/L ↓ HCO_3^- per 10 mm ↓ pCO_2

https://www.grepmed.com/images/1324/compensation-respiratory-nephrology-metabolic-diagnosis-alkalosis-acidbase

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VBG: 7.24/22.5/47.6/9

7. What is the acid-base status for this patient?

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VBG: 7.24/22.5/47.6/9

Winter's Formula: Expected pCO_2 = 1.5 [10] + 8 (+/- 2) = 23 +/- 2 mmHg

Metabolic Acidosis with full Respiratory compensation

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3.8	9.7	77	

VBG: 7.24/22.5/47.6/9

8. What type of Metabolic Acidosis does he have?

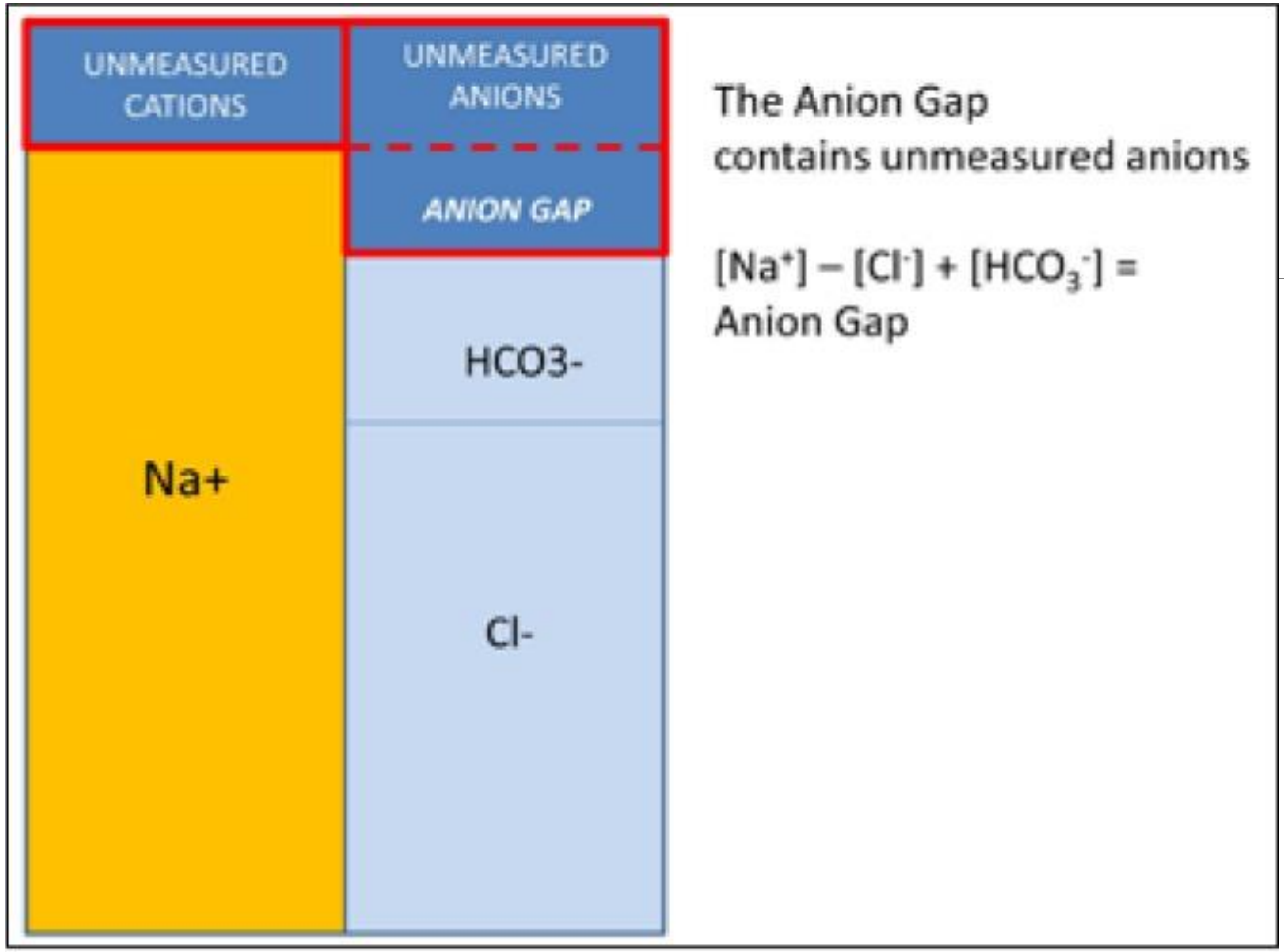

Fig 3

(a) Illustration of the "normal" anion gap

Normal AG = 140 – (104 + 24) = 12 mmol/L (Unmeasured Anions)

Hamilton, P. K., Morgan, N. A., Connolly, G. M., & Maxwell, A. P. (2017). Understanding Acid-Base Disorders. *The Ulster medical journal*, *86*(3), 161–166.

Albumin
40 gr/L = 12 mmol/L

Correct AG per serum Albumin:
Every 10 gr/L drop of Albumin from 40 gr/L add 2.5 mmol/L to Calculated AG

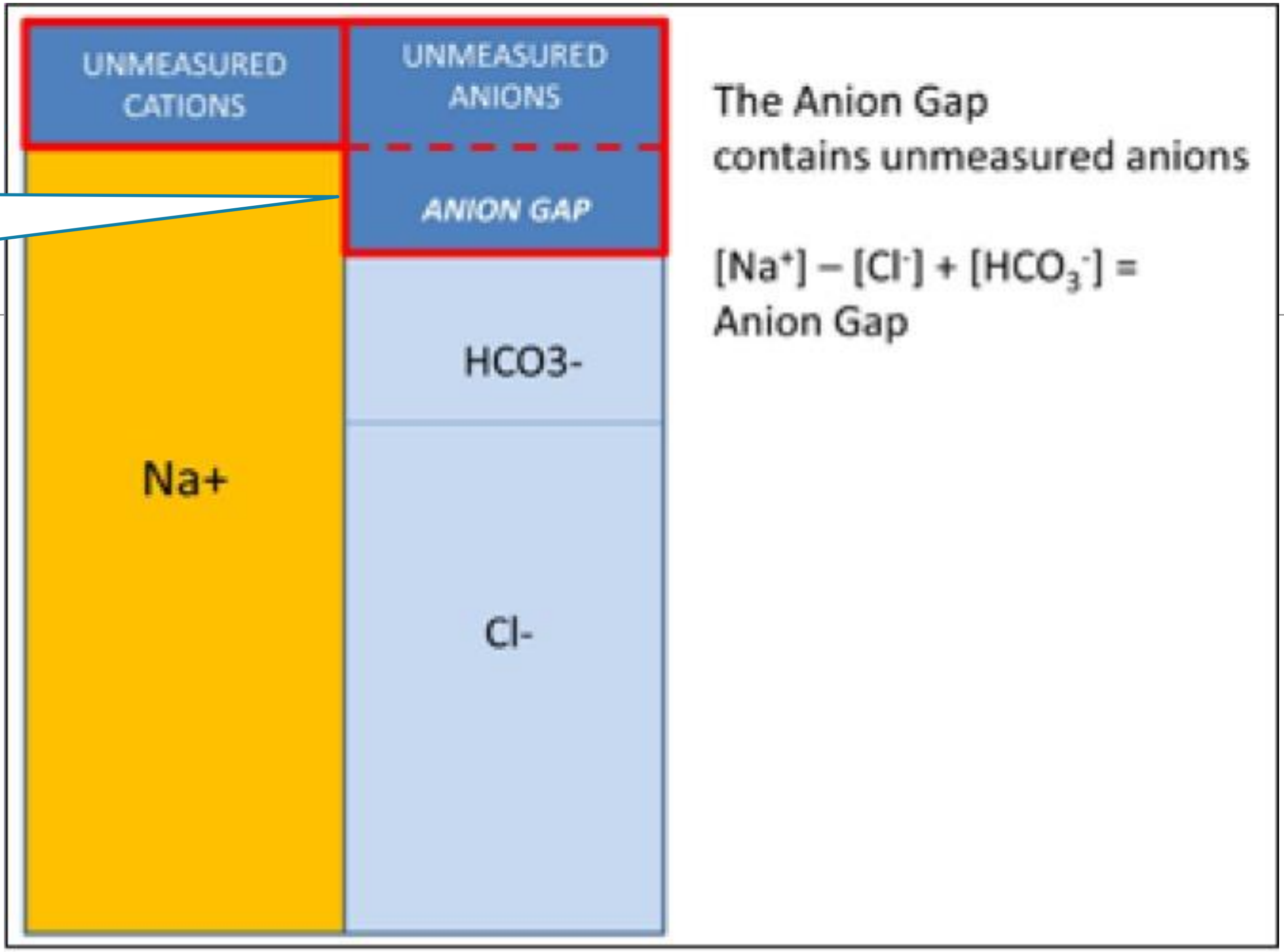

Fig 3
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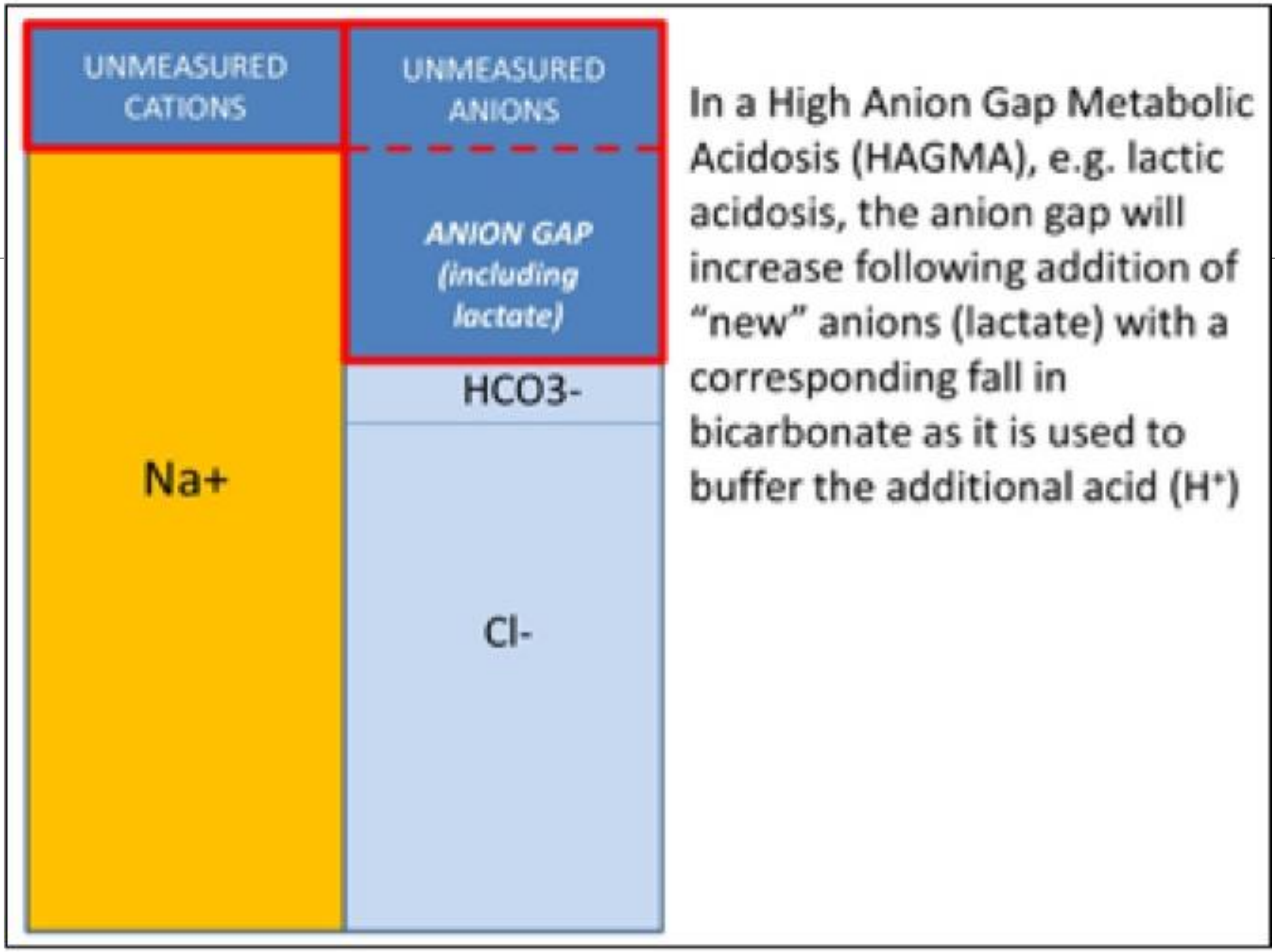

(b) High anion gap present in a metabolic acidosis

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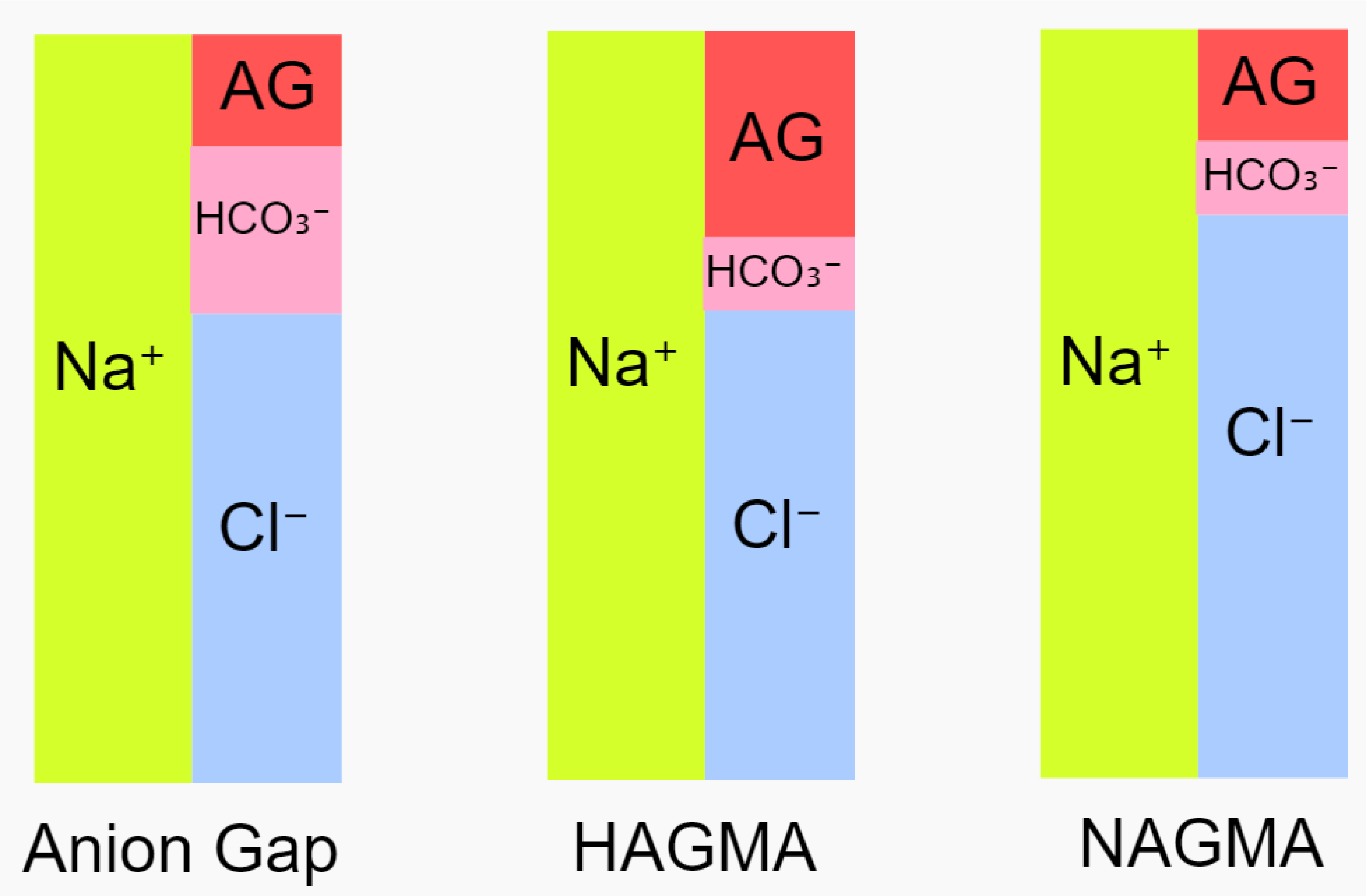
AG
HCO3⁻
Na+
Cl⁻
Anion Gap
AG
HCO3⁻
Na+
Cl⁻
HAGMA
AG
HCO3⁻
Na+
Cl⁻
NAGMA

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VBG: 7.24/22.5/47.6/9, Albumin 38

AG = 131 – (99 + 9.7) = 22 mmol/L

Normal AG = 12 mmol/L (Unmeasured Anions)

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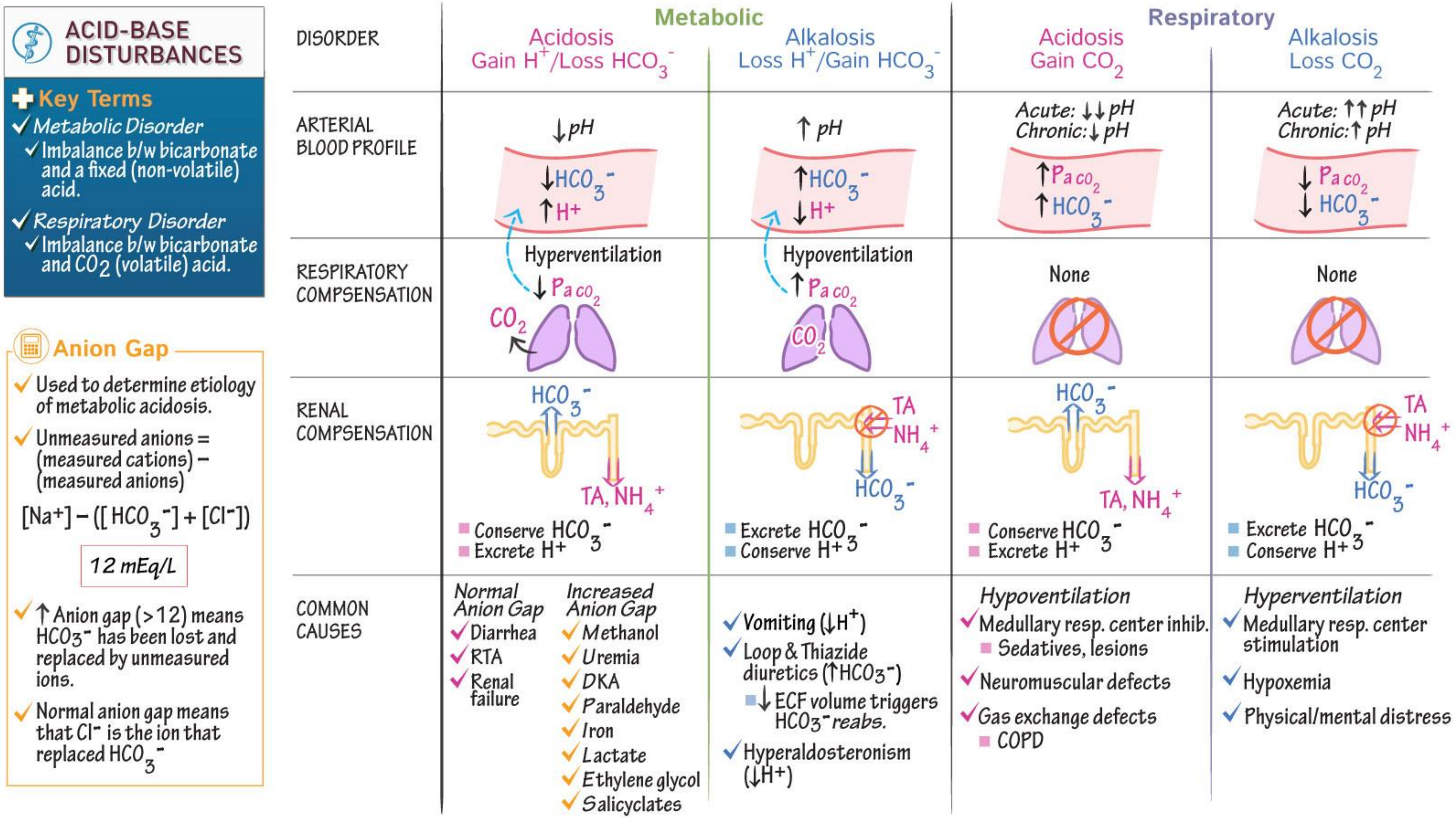
VBG: 7.24/22.5/47.6/9

High Anion Gap Metabolic Acidosis with full Respiratory compensation



https://drawittoknowit.com/course/physiology/acid-base/acid-base-balance/1326/alkalosis-and-acidosis

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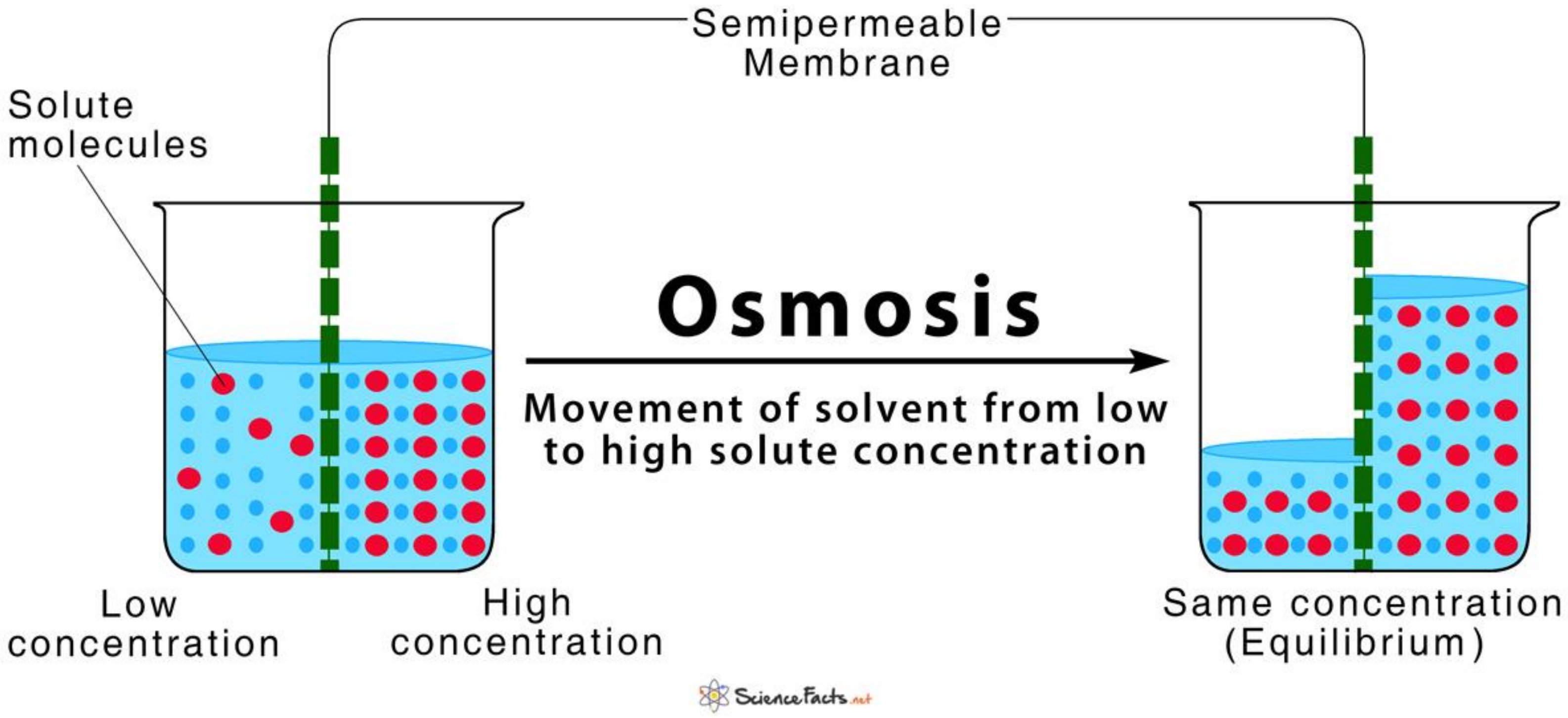
9. What type of hyponatremia does he have? And why?

ECF and ICF compartments are in ***osmotic equilibrium***

ICFosm = ECFosm = Posm



https://www.sciencefacts.net/osmosis.html

Correction of Serum [Na^+] for Hyperglycemia

- ✓**Every 5.5 mmol/L increase in serum Glucose from 5.5 mmol/L add 2.4 mmol/L to measured serum [Na^+]**

- ✓Gluc 16.1 mmol/L → 16.1-5.5 = 10.6 mmol/L

- ✓So (10.6/5.5) x 2.4 = 1.92 x 2.4 = 4.6 mmol/L

- ✓**Corrected [Na^+] = 131 + 4.6 = 135.6 mmol/L**

Spasovski et al. Clinical practice guideline on diagnosis and treatment of hyponatraemia. Nephrol Dial Transplant (2014) 0: 1–39.

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10. What is the difference between measured serum osmolarity and calculated serum osmolality? And what is serum osmol gap?

Plasma OsmolaRity vs. Plasma OsmolaLity:

- ✓ **Calculated Posm** (mOsm/L) **= 2 x [SNa⁺]**(mmol/L) + **Gluc** (mmol/L) + **Urea** (mmol/L)
  - ✓ **Calculated Posm** = (2 x 140) + 5 + 3 = **288 mOsm/L Plasma**
  - ✓ **Bulk of Plasma osmolarity from [Na⁺]**
- ✓ **Measured Posm = 286 mOsm/Kg Water**
- ✓ **1 L of Plasma (Solution) ≠ 1 L of Water (Solvent)**
- ✓ **1 L Normal Saline:**
  - ✓ Calculated OsmolaRity = 308 mOsm/L Solution
  - ✓ Measured OsmolaLity = 286 mOsm/kg Water

Finfer, S., Myburgh, J. & Bellomo, R. Intravenous fluid therapy in critically ill adults. Nat Rev Nephrol 14, 541–557 (2018).

Plasma OsmolaRity vs. Plasma OsmolaLity:

- ✓ Calculated Posm (mOsm/L) = 288 mOsm/L Plasma
- ✓ Measured Posm = 286 mOsm/Kg Water
- ✓ Osmol Gap = Measured Posm – Calculated Posm (up to 10 mOsm)
- ✓ Unmeasured osmoles (Usually alcohols!)

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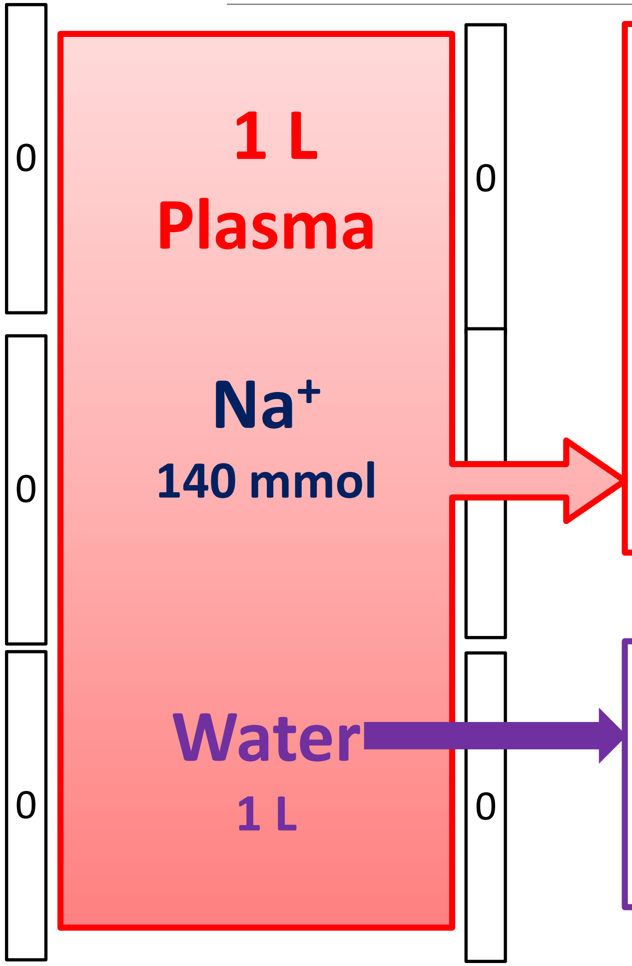
11. What is the difference between dysnatremia and volume status disturbance? And what are their controlling systems and their interaction?

Body Volume control vs. Body Water Balance control

- ✓ Volemia ~ Blood volume → ECF Volume → Total Body Volume
- ✓ 1 L Plasma = 1 L of water + 140 mmol of [Na^+]
- ✓ **Sodium Content ≠ Sodium Concentration**
  - ✓ **Sodium Content = Volume = Sodium Balance**
  - ✓ **Sodium Concentration = Natremia = Water Balance**

Sodium Content (Volume) vs. Sodium Concentration (*Natremia*)



Volume Control (Na Content *AND* Water) (Volume Receptors)

1. Salt Intake
2. Water Intake
3. RAAS
4. Natriuretic Peptides (ANP, BNP)
5. ADH

Water Control (Natremia = $[Na^+]$) (Osmoreceptors)

1. Thirst (Water Intake)
2. ADH

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Corrected $[Na^+]$ = 131 + 4.6 = 135.6 mmol/L

Dilutional hyponatremia with hypovolemic hyponatremia

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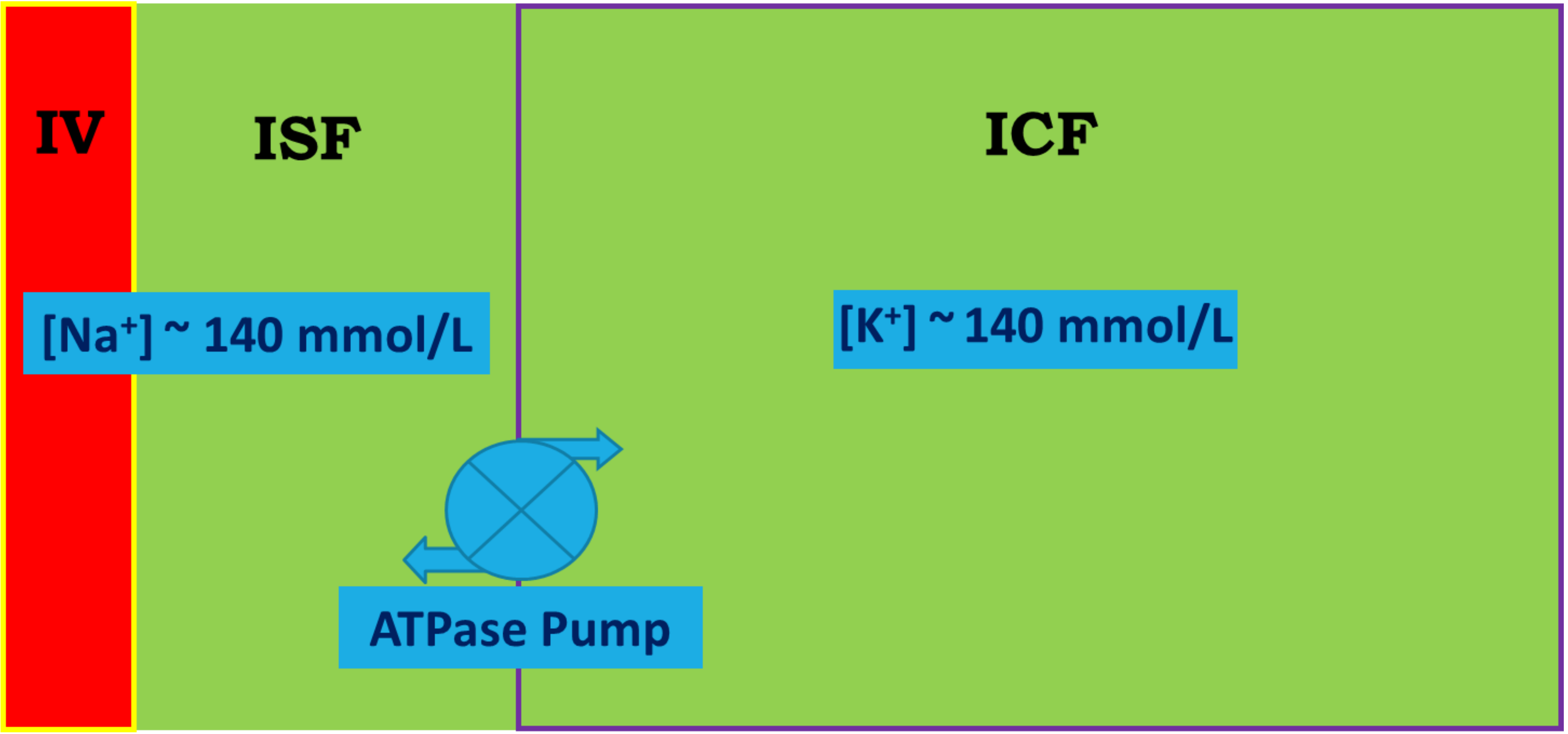
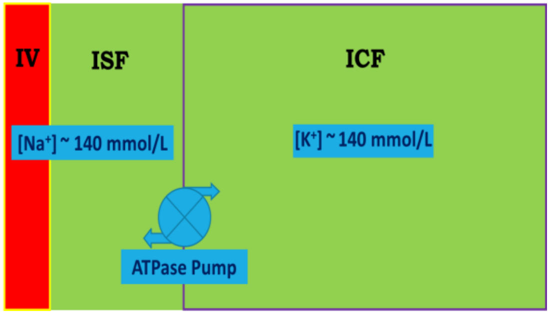
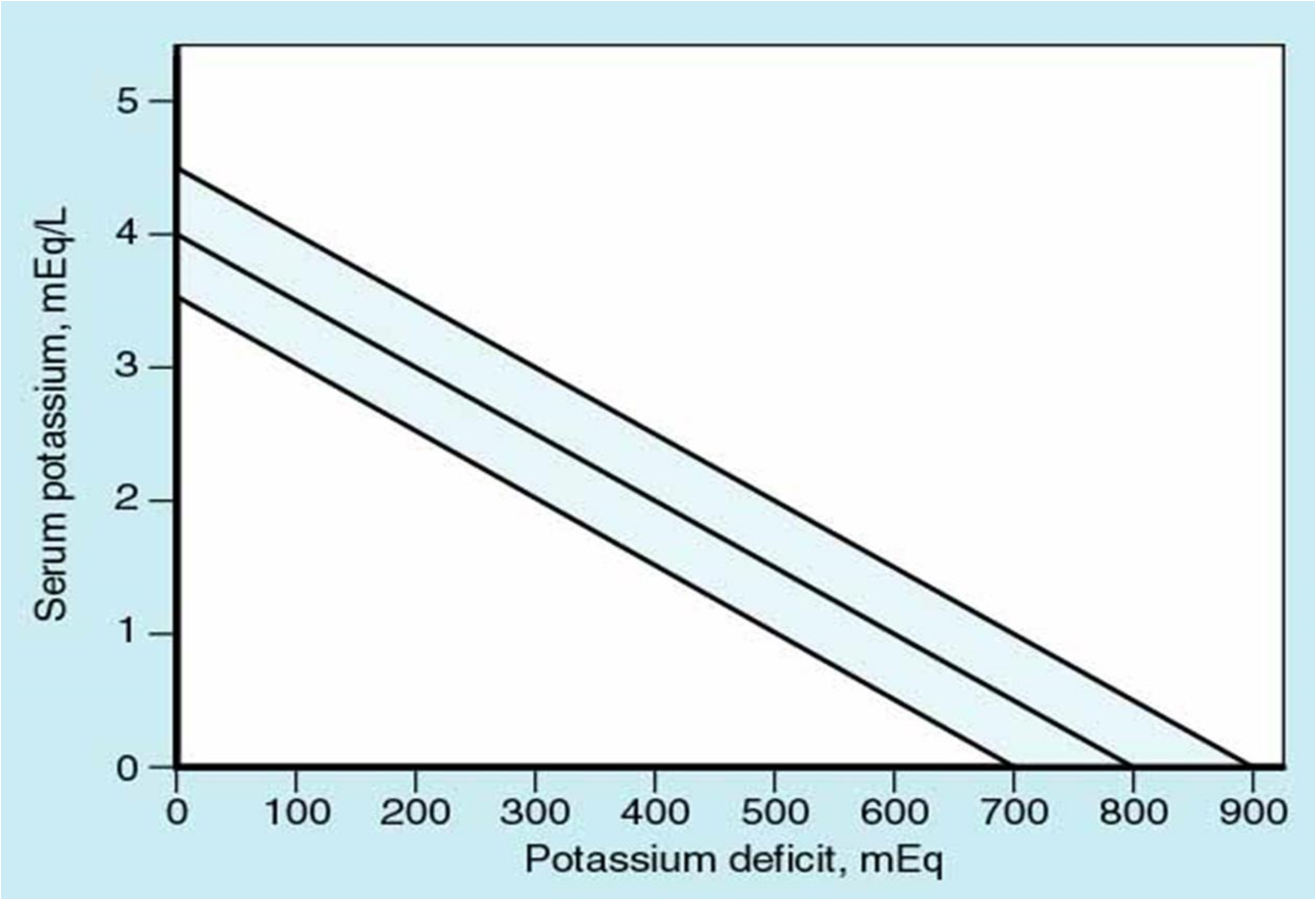
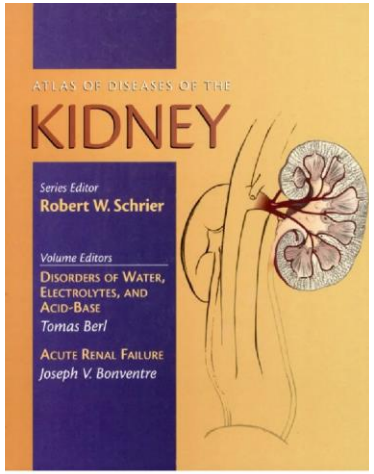
12. What is the potassium balance for this patient?


IV
ISF
ICF
[Na+] ~ 140 mmol/L
[K+] ~ 140 mmol/L
ATPase Pump

Potassium Deficit in relation to Serum SK^+







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13. What are the principles of Diabetic Ketoacidosis treatment?

Intended Learning Outcomes:

At the end of this lecture you should be able to:

1. Interpret Arterial Blood Gas report
2. Recognize Acidemia/Acidosis and Alkalemia/Alkalosis
3. Calculate Respiratory Compensation for metabolic disturbances
4. Calculate Anion Gap with correction for serum Albumin
5. Recognize the difference between volume status disturbance and dysnatremia
6. Formulate a management plan for DKA

Thank You!

Questions?