Acid-Base Case Study

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Patient Arrives in Emergency Room

- 22 year old female with “hyperventilation”

- Healthy female.
- No known medical problems.
- Was fine until a few days ago, when she noticed increasing urinary frequency with no pain.
- Over the past couple of days, she’s become aware of rapid, deep breathing.

Additional Information

- Patient has lost ~5 pounds over last 2 weeks, unintentionally.
- Prescription medications: oral contraceptives.
- Denies illicit drug use, except for marijuana.
- Physical examination is normal, except for
  - rapid pulse (110, normal 70)
  - deep, rapid breathing (30 /min, normal ~12 /min)

Physician's Initial Impressions

- Anxiety reaction
- Drug abuse
- Pulmonary embolus
  - unlikely: no pain, no swelling in leg
  - but possible and could be deadly
- Urinary tract infection
  - unlikely: no pain
  - easily diagnosed and treated

Initial Tests

- Pulse oximetry: O_2 sat = 100%
- Urine dipstick testing:
  - no white blood cells, no bacteria, no blood
- Urine drug screen:
  - no drugs of abuse detected
- D-Dimer:
  - 140 (values <500 are reassuring)
  - more on this test later in course

Other Tests (1)

- co-oximetry:
  - confirm pulse oximetry O_2 sat
  - what if there's an abnormal hemoglobin present?

- results:
  - 98% oxyhemoglobin (O_2 saturation)
  - 1% methemoglobin (normal value)
  - 3% carboxyhemoglobin (normal for Boston)

- very reassuring

Other Tests (2)

- ABGs:
  - we need to check PO_2
  - might as well check acid-base, too

- results

  as PCO_2 falls, PO_2 rises

  - PO_2: 120 mmHg (13.3 kPa) (possible? why?)
  - PCO_2: 15 mmHg (2.00 kPa)
  - HCO_3: 6 mmol/L (acid-base status?)

Other Tests (2)

- results
  - PO_2: 120 mmHg (13.3 kPa)
  - PCO_2 : 15 mmHg (2.00 kPa)
  - HCO_3^- : 6 mmol/L (acid-base status?)

- calculate H^+/pH
  - 24(15/6) = 60 (increase of 20 nmol/L)
  - → decrease of 0.20 pH units, so pH=7.20
  - → metabolic acidosis, with compensation
  - i.e., HCO_3^- is low, and PCO_2 is low

Summary: Acid-Base Disturbances (with compensation)

Disturbance	PCO_2	$HCO3^-$	H^+	pH	Common Causes
Respiratory Alkalosis	⇓	↓	↓	↑	Sepsis Anxiety
Respiratory Acidosis	⇑	↑	↑	↓	Chronic Lung Disease Poor Ventilator Settings
Metabolic Alkalosis	↑	⇑	↓	↑	Vomiting Diuretic Therapy
Metabolic Acidosis	↓	⇓	↑	↓	Diarrhea Diabetic Ketoacidosis

PCO_2 and HCO_3 always move in same direction!

- if only one changes → acute disturbance
- if different direction → >1 disturbance!

Other Tests (3)

- With diagnosis of metabolic acidosis,
  we need to check anion gap status
  so we need __________

- Electrolytes
  - Na = 130, K = 5.2, Cl = 90, HCO_3 = 6
  - Anion Gap = 130 – (90 +6) = 24 (normal = 11)
  - → increased anion gap metabolic acidosis

Other Tests (4)

- Whoa!
- How about that Na of 130 mEq/L?
- Is it real? Could it be pseudohyponatremia?
- How can we confirm it? (2 ways)
  - non-dilutional ISE
  - measured versus calculated osmolality

Osmolality

- measurement: freezing point depression
  - not boiling point elevation (alcohols)
  - the principle underlying ice melt preparations
- calculation
  - very few substances in human serum that make significant contributions to osmolality
  - complicated by our (US) refusal to use SI units

Calculation of Osmolality: Trivial In All But Three Countries

map from Wikipedia.com

- Osmolality is a colligative property, corresponds to
  - number of particles (millimoles)
  - not to the mass of those particles (milligrams)

Calculated Osmolality (Na)

- normal [Na] = 140 mEq/L
- 1 mmol Na = 1 mEq Na (valence 1)
- every Na must be balanced by an anion in serum,
  so, for convenience, we multiply [Na] by 2
  rather than adding up all the anions in serum
- typical Na (and associated anions) contribution to osmolality:
  140 X 2 = 280 mosm/kg

Calculated Osmolality (Glucose)

- normal [Glucose] = 100 mg/dL
- convert mg to mmol and dL to L

- 1 mmol Glucose = 180 mg Glucose ($C_6H_{12}O_6$)
- 100 mg/dL / 180 mg/mmol → 0.556 mmol/dL
- 0.556 mmol/dL X 10 dL/L → 5.56 mmol/L

- In general, to convert conventional units to SI units:
  - conventional units (mg/dL) / molecular weight * 10

- typical glucose contribution to osmolality:

  100 / 180 x 10 = 6 mosm/kg

Calculated Osmolality (Urea)

- normal [BUN] = 12 mg/dL
- convert mg to mmol and dL to L

- 1 mmol Urea = 60 mg Urea (NH_2-CO-NH_2)
- BUT we report Urea Nitrogen
- 1 mmol Urea = 28 mg Urea Nitrogen (2 Ns per molecule)

- Using our general formula, the typical urea contribution to osmolality is:

  12 / 28 x 10 = 4 mosm/kg

Calculated Osmolality (Normal & This Case)

- In serum without alcohols or drugs:
- CalculatedOsmolality = [Na] x 2 + (Glucose/18) + BUN/2.8)
- Normally: 140 x 2 + (100/18) + (12/2.8) = 290 mosm/kg
- Our patient:

  Na = 130

  Glucose = 423

  BUN = 12

  ➔ 130 x 2 + (423/18) + (12/2.8) = 260 + 24 + 4 = 288
- Measured Osmolality = 290
- This implies that the measured Na of 130 is real
- Had it been pseudohyponatremia, the calculated osmolality would have been low

This Is **Not** Pseudohyponatremia

- This patient has real hyponatremia
- The measurement is accurate

- It is true that the high glucose concentration is leading to the low Na concentration
- However, labs should not "correct" the [Na]
  - i.e., try to estimate what the [Na] would be if glucose were returned to normal
  - clinicians can do this themselves if they want
  - fraught with difficulties

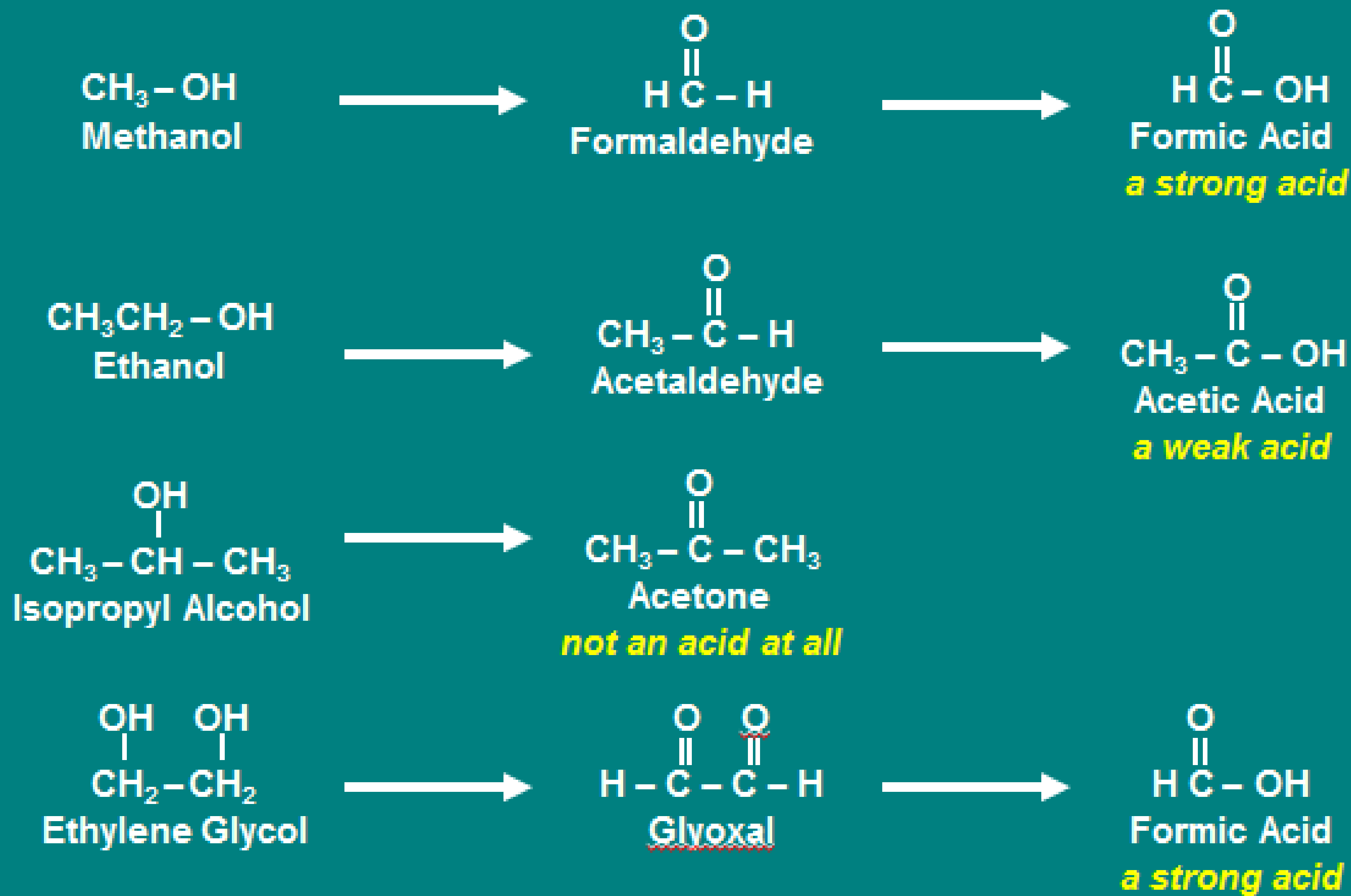
Other Tests (5): MUDPILES

- Causes: Metabolic Acidosis with Increased Anion Gap
  - **M**ethanol: Possible. History not suggestive.
  - **U**rea: Ruled out by normal BUN.
  - **D**iabetes: YES: very high glucose
  - **P**ropylene Glycol: Possible. History not suggestive.
  - **I**soniazid: Possible. History not suggestive.
  - **L**actate: Not likely: no shock. Easily measured.
  - **E**thylene glycol: Possible. History not suggestive.
  - **S**alicylate: Not likely. Easily measured.

- Diagnosis = Diabetic Ketoacidosis

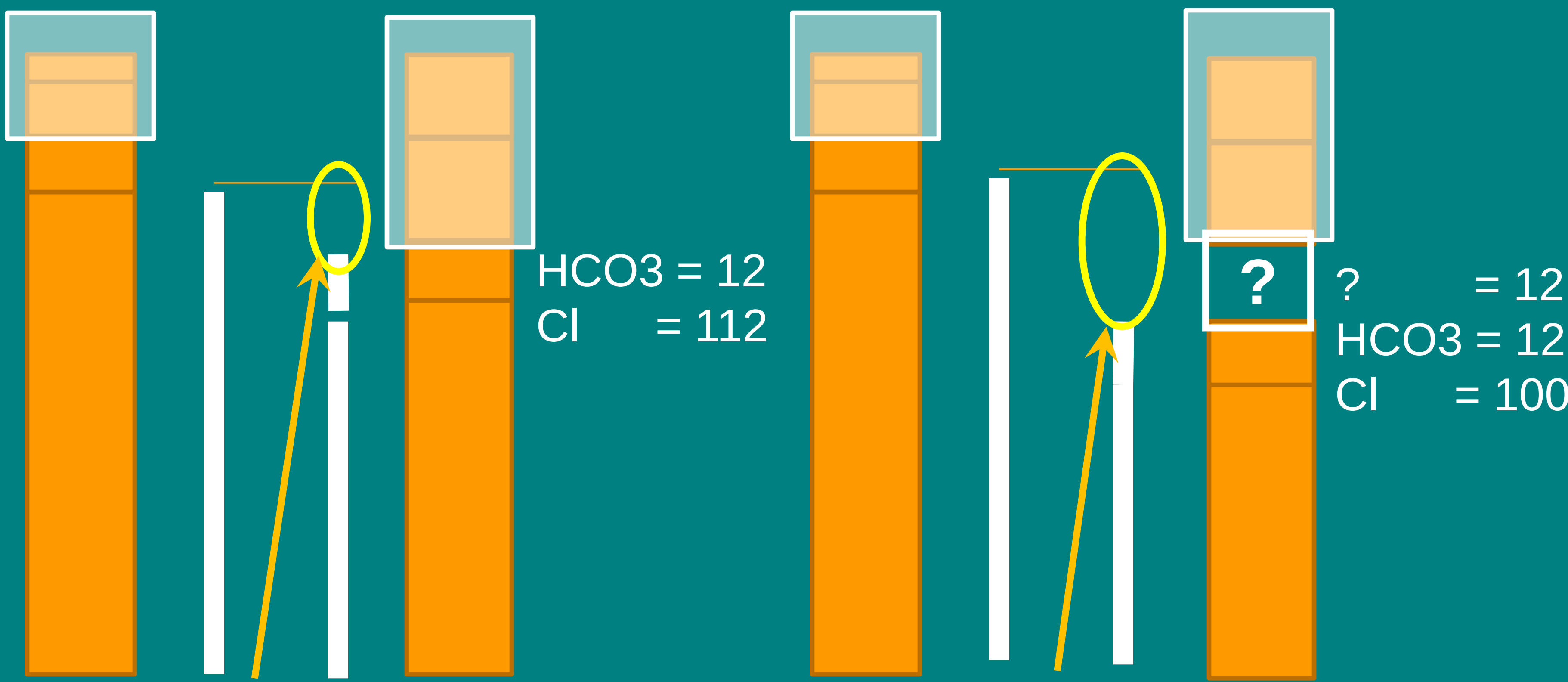
Alcohol Metabolism:

Why Some Alcohols Lead to Increased Anion Gap



Metabolic Acidosis

HCO_3- Decreases from 24 to 12

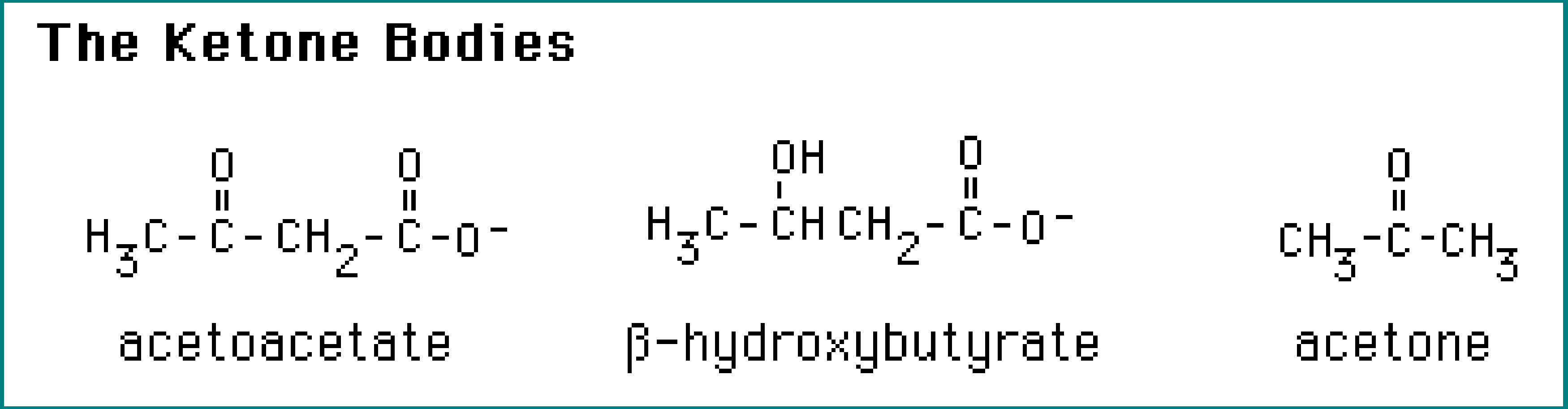


Normal anion gap
Chloride has increased,
replacing lost HCO3

Increased anion gap
Chloride has not changed
A new anion has replaced
lost HCO3

So What Are Those Increased "Unmeasured" Anions?

- In diabetic ketoacidosis, several acids accumulate, two of which are among the "ketone bodies"



- Note: **β-hydroxybutyrate** is not a ketone
- Note: **acetone** is not an anion
  - Does not contribute to increased anion gap
  - Does contribute to osmolality

Not an Atypical Presentation of Diabetes

- Urinary frequency
  - [glucose] is beyond kidney tubules capacity for reabsorption
  - draws/keeps water in kidney tubules, causing an osmotic diuresis
- Fluid loss translates into weight loss
- As acidosis develops and intensifies
  - respiratory compensation with hyperventilation
  - can appear bizarre, as it did in this case

Topics Reviewed in this Case

- relationship between PO_2 and PCO_2 in patients
- calculation of H^+/pH from PCO_2 and HCO_3
- evaluation of acid-base disturbance
- use of anion gap in metabolic acidosis (MUDPILES)
- evaluation for pseudohyponatremia
- SI Units
- calculation of osmolality
- structures of ketone bodies

“Tests” Discussed in this Case

- pulse oximetry
- co-oximetry
- Arterial Blood Gases (PO_2, PCO_2, pH)
- electrolytes (Na, K, Cl, and HCO_3)
- osmolality (as well as Glucose and BUN)
- MUDPILES
- metabolism of alcohols
- ketone bodies