Watson's Acid Base Disorders Worksheet:

(Adapted from Rupard's Acid base Worksheet and Pocket Medicine, 2nd Edition)

Step 1: Gather Necessary Data: ABG **and** Chem 7

Step 2: Characterize the chem 7: Acidosis vs. Alkalosis

Step 3a: Determine the Primary Disorder: Look at the ABG pH to determine the primary disorder: Acidemia <7.4 vs. Alkalemia >7.4

Step 3b: Look at the $PaCO_2$

If patient has primary acidemia based on ABG pH and $PaCO_2$ is >40, then patient's acidosis is respiratory; If <40, then metabolic

If patient has primary alkalosis and $PaCO_2$ is >40, then patient's alkalosis is metabolic; if <40 then respiratory

Primary disorder (based on ABG pH)	Metabolic problem	ABG pH	Chem 7 HCO_3	$PaCO_2$ (ABG)
Metabolic Acidosis	Gain H^+ or loss HCO_3	↓	↓	↓
Metabolic Alkalosis	Gain HCO_3 or loss H^+	↑	↑	↑
Respiratory Acidosis	Hypoventilation	↓	↑	↑
Respiratory Alkalosis	Hyperventilation	↑	↓	↓

Step 4: Determine if there is a secondary disorder by checking the physiologic compensation. If a primary metabolic process is present then check the respiratory compensation (calculate expected $PaCO_2$). If a primary respiratory process is present check the renal compensation (calculate expected HCO_3).

4a: If primary d/o is **metabolic acidosis** use ***Winter's Formula*** to calculate the expected $PaCO_2 = 1.5 \times HCO_3 + 8\pm2$

4b: If primary d/o is **metabolic alkalosis**: expected $PaCO_2$ = ↑6mmHg per 10 mmol/L↑HCO_3

4c: If primary d/o is **respiratory acidosis**: Expected HCO_3 ↑1 (**acute**) to 3.5 (**chronic**) mmol/L per 10 mmHg ↑$PaCO_2$

*If you like to memorize formulas: Expected $HCO_3 = 24 + (0.1 \times \Delta PaCO_2)$ for **ACUTE** process; Expected $HCO_3 = 24 + (0.35 \times \Delta PaCO_2)$ for **CHRONIC** process*

4d: If primary d/o is **respiratory alkalosis**: Expected HCO_3 ↓2 (**acute**) to 5 (**chronic**) mmol/L per 10 mmHg ↓$PaCO_2$

*If you like to memorize formulas: Expected $HCO_3 = 24 - (0.2 \times \Delta PaCO_2)$ for **ACUTE** process; Expected $HCO_3 = 24 - (0.5 \times \Delta PaCO_2)$ for **CHRONIC** process*

Step 5: Check for an anion gap (Na – Cl – HCO_3). If anion gap present, calculate delta (Δ) anion gap and delta (Δ) HCO_3. If no anion gap skip to 6.

ΔGap = calculated gap – expected gap (usually 12)

(NOTE: expected gap is based on albumin! Assuming normal albumin = 4 then expected gap is 3 x 4 = 12. Expected gap is always 3 x albumin.)

$\Delta HCO_3 = 24 - HCO_3$

DELTA DELTA INTERPRETATION OPTION #1	INTERPRETATION OPTION #2	DELTA DELTA INTERPRETATION OPTION #3
If ΔGap = ΔHCO_3 then a third disorder is NOT present	**Ratio method = ΔGap / ΔHCO_3**	1mmol acid titrates 1mmol bicarb (+ΔAG= - ΔHCO_3)
If ΔGap greater than ΔHCO_3 then additional metabolic alkalosis is present	<1 = AGMA+NAGM; 1-2 = Pure AGMA	So add ΔGap + measured bicarb
If ΔGap less than ΔHCO_3 then additional non-gapped acidosis is present	>2 = AGMA + Metabolic alkalosis	If >24 then met alkalosis; if <24 then NAGMA present

Step 6: If non-anion gapped acidosis is present then calculate urine anion gap. UAG = (Urine Na + Urine K) – Urine Cl.

Positive UAG = inappropriately low urine ammonium excretion = Renal issue (i.e. renal tubular acidosis).

Negative UAG = high urine ammonium = non-renal cause (i.e. GI issue/diarrhea)

Step 7: Figure out what's causing the problem!! Then fix it!!

Anion Gapped Metabolic Acidosis	Non-Gap Metabolic Acidosis	Acute Respiratory Acidosis	Metabolic Alkalosis	Respiratory Alkalosis
"MUDPILERS" **M**ethanol **U**remia **D**KA/Alcoholic KA **P**araldehyde **I**soniazid **L**actic Acidosis **E**TOH/**E**thylene glycol **R**habdomyolysis/**R**enal failure **S**alicylates **GOLDMARK** **G**lycols, **O**xyproline(Tylenol) **L**actate or D-Lactate **M**ethanol, **A**SA, **R**enal, **K**etones	**"HARDUPS"** **H**yperalimentation **A**cetozolamide (carbonic anhydrase inhibitors) **R**enal tubular acidosis **D**iarrhea **U**retero-pelvic shunt **P**ost-hypocapnea **S**pironolactone	***Anything that causes hypoventilation, i.e.:*** CNS depression (Drugs/CVA) Airway obstruction Pneumonia Pulmonary edema Hemo/pneumothorax Myopathy ***Chronic resp acidosis:*** COPD Restrictive lung disease	**"CLEVER PD"** **C**ontraction (volume) **L**icorice **E**ndocrine disorders (Hyperaldosteronism, Cushing's) **V**omiting **E**xcess alkali **R**efeeding alkalosis **P**ost hypercapnea **D**iuretics *Also severe hypokalemia* (Gitelman's, Bartter's syndrome)	**"CHAMPS"** ***Anything that causes hyperventilation*** **C**NS disease **H**ypoxia (PE, PNA, IPF) **H**epatic failure **A**nxiety **M**ech Ventilators **P**regnancy/**P**rogesterone/**P**ain **S**alicylates/**S**epsis

Watson's Acid Base Worksheet page 2 (Another Approach for Metabolic Acidosis and Alkalosis)

Step 1: Characterize the Chem 7: Acidosis vs. Alkalosis

Step 2: look at the ABG pH: Acidemia vs. Alkalemia

Step 3: Metabolic Acidosis vs. Metabolic Alkalosis

Metabolic Acidosis

↓

Calculate Anion Gap

↙ ↘

Anion Gapped Acidosis

↓

Check albumin; determine expected gap

↓

↓

Assess respiratory compensation

WINTER'S FORMULA

($PaCO_2 = 1.5 \times HCO_3 + 8 \pm 2$)

↓

Calculate ΔGap

Calculate ΔHCO_3

↓

↓

↓

↓

↓

↓

↓

If ΔGap = ΔHCO_3 then a third disorder is NOT present
If ΔGap greater than ΔHCO_3 then additional metabolic alkalosis is present
If ΔGap less than ΔHCO_3 then additional non-gapped acidosis is present

Non Gap Acidosis

↓

↓

↓

↓

Calculate urine anion gap (UAG)=

(Urine Na + Urine K) – Urine Cl

+ UAG = low urine ammonium

+ UAG = RTA present

- UAG = high urine ammonium

- UAG = GI issue/diarrhea

NOTE: *You cannot use UAG when patient is not euvolemic or is ketotic!! Will give false + UAG*

If ingestion of toxin suspected can calculate osmolar gap

Osmolar gap = Expected serum osmol – Measured serum osmol

Expected serum osmols = 2 x Na + Glu/18 + BUN/2.8 + ETOH/4.5

Osmolar Gap > 10 is positive

Metabolic Alkalosis

Check urine chloride (indirect measure of volume status)

NOTE: *Can't use FENa as urine Na will be high due to $NaHCO_3$ binding in kidney to correct alkalosis*

If Urine Cl < 10 = volume depletion (kidney retaining chloride)

If Urine Cl > 20 = NOT volume depletion so look for other causes (CLEVER PD).

Differential Diagnosis of an Elevated Plasma Osmolal Gap	
With Anion Gap Metabolic Acidosis	**Without Metabolic Acidosis**
Ethylene glycol ingestion	Ethanol or isopropyl alcohol ingestion
Methanol ingestion	Diethyl ether ingestion
ESRD (eGFR<10mL/min) without regular dialysis	Infusion of non-conductive glycine, sorbitol or mannitol solutions
Diabetic ketoacidosis	Severe hyperproteinemia
Alcoholic ketoacidosis	Severe hyperlipidemia
Formaldehyde ingestion	
Paraldehyde ingestion	