

Type of secretion	Volume (ml/24 hr)	Na (mEq/L)	K (mEq/L)	Cl (mEq/L)	HCO <sub>3</sub> (mEq/L)
Salivary . . . . .	1,500 (500-2,000)	10 (2-10)	26 (20-30)	10 (8-18)	30
Stomach . . . . .	1,500 (100-4,000)	60 (9-116)	10 (0-32)	130 (8-154)	
Duodenum . . . . .	(100-2,000)	140	5	80	
Ileum . . . . .	3,000 (100-9,000)	140 (80-150)	5 (2-8)	104 (43-137)	30
Colon . . . . .	.....	60	30	40	
Pancreas . . . . .	.....	140	5	75	115
Bile . . . . .	(100-800) (50-800)	(113-185) (131-164)	(3-7) (3-12)	(54-95) (89-180)	100 35

Fig. 2-2. Chemical composition of body fluid compartments.

154 mEq/l		153 mEq/l		200 mEq/l	
CATIONS	ANIONS	CATIONS	ANIONS	CATIONS	ANIONS
Na <sup>+</sup> 142	Cl <sup>-</sup> 103	Na <sup>+</sup> 144	Cl <sup>-</sup> 114	K <sup>+</sup> 150	HPO <sub>4</sub> <sup>3-</sup> 150 SO <sub>4</sub> <sup>2-</sup> 150
HCO <sub>3</sub> <sup>-</sup> 27		HCO <sub>3</sub> <sup>-</sup> 30		HCO <sub>3</sub> <sup>-</sup> 10	
SO <sub>4</sub> <sup>2-</sup> 3		SO <sub>4</sub> <sup>2-</sup> 3		Mg <sup>++</sup> 40	Protein 40
PO <sub>4</sub> <sup>3-</sup> 3		PO <sub>4</sub> <sup>3-</sup> 3		Na <sup>+</sup> 10	
K <sup>+</sup> 4		K <sup>+</sup> 4			
Ca <sup>++</sup> 5	Organic Acids 5	Ca <sup>++</sup> 3	Organic Acids 5		
Mg <sup>++</sup> 3	Protein 16	Mg <sup>++</sup> 2	Proteins 1		

PLASMA                    INTERSTITIAL FLUID                    INTRACELLULAR FLUID

Table 2-7. SODIUM (SALT) EXCHANGE (60-80 kg man)

Sodium exchange	Average	Minimal	Maximal
Sodium gain:			
Diet . . . . .	50-90 mEq/day	0	75-100 mEq/hr (oral)
Sodium loss:			
Skin (sweat) . .	10-60 mEq/day*	0	300 mEq/hr
Urine . . . . .	10-80 mEq/day	<1 mEq/day†	110-200 mEq/L‡
Intestines . . . .	0-20 mEq/day	0	300 mEq/hr

\* Depending on the degree of acclimatization of the individual.

† With normal renal function.

‡ With renal salt wasting.

Routes	Average daily volume, ml	Minimal, ml	Maximal, ml
H <sub>2</sub> O gain:			
Sensible:			
Oral fluids . . . . .	800-1,500	0	1,500/h
Solid foods . . . . .	500-700	0	1,500
Insensible:			
Water of oxidation . .	250	125	800
Water of solution . . .	0	0	500
H <sub>2</sub> O loss:			
Sensible:			
Urine . . . . .	800-1,500	300	1,400/h (diabetes insipidus)
Intestinal . . . . .	0-250	0	2,500/h
Sweat . . . . .	0	0	4,000/h
Insensible:			
Lungs and skin . . . .	600-900	600-900	1,500

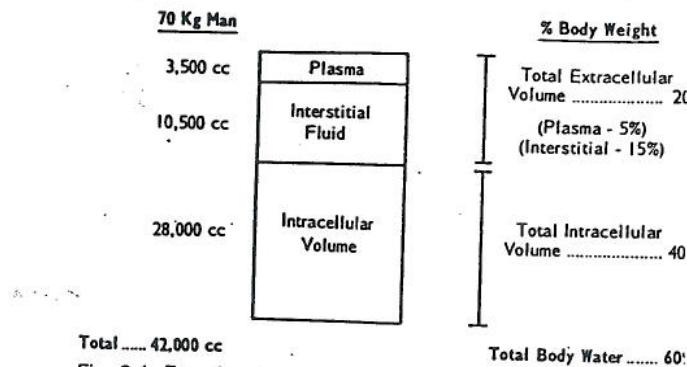


Fig. 2-1. Functional compartments of body fluids.

Table 2-8. COMPOSITION OF PARENTERAL FLUIDS  
Electrolyte content (mEq/L)

Solutions	Cations					Anions		
	Na	K	Ca	Mg	NH <sub>4</sub>	Cl	HCO <sub>3</sub> <sup>-</sup>	HPO <sub>4</sub> <sup>3-</sup>
Extracellular fluid . . . . .	142	4	5	3	.3	103	27	3
Lactated Ringer's	130	4	2.7	.....	.....	109	28*	.....
0.9% sodium chloride (saline)	154	.....	.....	.....	.....	154	.....	.....
M/6 sodium lactate . . . . .	167	.....	.....	.....	.....	.....	167*	.....
M (molar) sodium lactate . . . . .	1,000	.....	.....	.....	.....	.....	1,000*	.....
3% sodium chloride . . . . .	513	.....	.....	.....	.....	513	.....	.....
5% sodium chloride . . . . .	855	.....	.....	.....	.....	855	.....	.....
0.9% ammonium chloride . . . . .	.....	.....	.....	.....	.....	168	168	.....

\*Present in solution as lactate which is converted to bicarbonate.

(Table 2-1) EXTRACELLULAR FLUID VOLUME

Type of sign	Deficit		Excess	
	Moderate (5-10%)	Severe (>10%)	Moderate	Severe
Central nervous system	Sleepiness Apathy Slow responses Anorexia Cessation of usual activity	Decreased tendon reflexes. Anesthesia distal extremities Stupor Coma	None	None
Gastrointestinal	Progressive decrease in food consumption	Nausea, vomiting Refusal to eat Silent ileus and distension	At surgery: Edema of stomach, colon, lesser and greater omenta and small bowel mesentery	
Cardiovascular	Orthostatic hypotension Tachycardia Collapsed veins Collapsing pulse	Cutaneous lividity Hypotension Distant heart sounds Cold extremities Absent peripheral pulses	Elevated venous pressure Distension of peripheral veins Increased cardiac output Loud heart sounds Functional murmurs Bounding pulse High pulse pressure Increased pulmonary 2d sound Gallop	Pulmonary edema
Tissue	Soft, small tongue with longitudinal wrinkling Decreased skin turgor	Atonic muscles Sunken eyes	Subcutaneous pitting edema Basilar rales	Anasarca Moist rales Vomiting Diarrhea
Metabolic	Mild decrease temperature, 97-99°F	Marked decrease temperature, 95-98°F	None	None

(Table 2-2) ACUTE CHANGES IN OSMOLAR CONCENTRATION

Type of signs	Hyponatremia (water intoxication)	① ADH ↑ ② ADH inappropriate ③ Renal failure ④ Hyperglycemia	Hypernatremia (water deficit)	① D.I. ② Osm. diuresis ③ Thirst ④ Diarrhea, T.I.L.
Central nervous system	Moderate: Muscle twitching Hyperactive tendon reflexes Increased intracranial pressure (compensated phase)	Severe: Convulsions Loss of reflexes Increased intracranial pressure (decompensated phase)	Moderate: Restlessness Weakness	Severe: Delirium Maniacal behavior
Cardiovascular	Changes in blood pressure and pulse secondary to increased intracranial pressure		Tachycardia Hypotension (if severe)	
Tissue	Salivation, lacrimation, watery diarrhea "Fingerprinting" of skin (sign of intracellular volume excess)		Decrease saliva and tears Dry and sticky mucous membranes Red, swollen tongue Skin flushed	
Renal	Oliguria progressing to anuria		Oliguria	
Metabolic	None		Fever	

Table 2-3. ACIDOSIS-ALKALOSIS

Type of acid-base disorder	Defect	Common causes	$\frac{BHCO_3}{H_2CO_3} = \frac{20}{1}$	Compensation
Respiratory acidosis	Retention of CO <sub>2</sub> (Decreased alveolar ventilation) $V_A = \frac{V_{CO_2}}{P_{a,CO_2}}$	Depression of respiratory center—morphine, CNS injury Pulmonary disease—emphysema, pneumonia	↑ Denominator Ratio less than 20:1	Renal Retention of bicarbonate, excretion of acid salts, increased ammonia formation Chloride shift into red cells
Respiratory alkalosis	Excessive loss of CO <sub>2</sub> (Increased alveolar ventilation)	Hyperventilation: Emotional, severe pain, assisted ventilation, encephalitis	↓ Denominator Ratio greater than 20:1	Renal Excretion of bicarbonate, retention of acid salts, decreased ammonia formation
Metabolic acidosis	Retention of fixed acids or Loss of base bicarbonate	Diabetes, azotemia, lactic acid accumulation, starvation Diarrhea, small bowel fistulae	↓ Numerator Ratio less than 20:1	Pulmonary (rapid) Increase rate and depth of breathing Renal (slow) As in respiratory acidosis
Metabolic alkalosis	Loss of fixed acids Gain of base bicarbonate Potassium depletion	Vomiting or gastric suction with pyloric obstruction Excessive intake of bicarbonate Diuretics	↑ Numerator Ratio greater than 20:1	Pulmonary (rapid) Decrease rate and depth of breathing Renal (slow) As in respiratory alkalosis

Table 2-4. RESPIRATORY AND METABOLIC COMPONENTS OF ACID-BASE DISORDERS

Type of acid-base disorder	Acute (uncompensated)			Chronic (partially compensated)		
	pH	P <sub>CO<sub>2</sub></sub> (respiratory component)	Plasma HCO <sub>3</sub> <sup>-*</sup> (metabolic component)	pH	P <sub>CO<sub>2</sub></sub> (respiratory component)	Plasma HCO <sub>3</sub> <sup>-*</sup> (metabolic component)
Respiratory acidosis . . .	↓↓	↑↑	N	↓	↑↑	↑
Respiratory alkalosis . . .	↑↑	↓↓	N	↑	↓↓	↓
Metabolic acidosis . . .	↓↓	N	↓↓	↓	↓	↓
Metabolic alkalosis . . .	↑↑	N	↑↑	↑	↑?	↑

\* Measured as standard bicarbonate, whole blood buffer base, CO<sub>2</sub> content or CO<sub>2</sub> combining power. The *base excess value* is positive when the standard bicarbonate is above normal and negative when the standard bicarbonate is below normal.