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Blood Buffer System & Acid–Base Balance

Exam — Blood & Hemoglobin

Pre-med/IB-style questions on what buffers are, the bicarbonate buffer system, why CO_2 matters, and how lungs and kidneys maintain blood pH. Includes tricky scenarios for respiratory vs metabolic acidosis/alkalosis and compensation.

50 items — Printable Exam

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1 **Which definition BEST describes a chemical buffer?**

A A substance that makes pH exactly 7 in all solutions

B A mixture that prevents any chemical reaction from occurring

C A solution that resists pH change by containing a weak acid and its conjugate base

D A strong acid that neutralizes any base instantly

E A salt solution that always becomes neutral when diluted

2 **The main buffer system in human blood plasma is best represented by which equilibrium?**

A $H_2O \quad H^+ + OH^-$

B $CO_2 + H_2O \quad H_2CO_3 \quad H^+ + HCO_3^-$

C $NaCl \quad Na^+ + Cl^-$

D $O_2 + Hb \quad HbO_2^-$

E Glucose $\quad$ lactate

3 **Carbonic anhydrase is important in blood because it:**

A Breaks down hemoglobin into amino acids

B Speeds up the conversion between $CO_2 + H_2O$ and H_2CO_3

C Pumps bicarbonate out of the kidneys using ATP

D Converts glucose into glycogen

E Destroys acids by turning them into salts

4 **Why is the bicarbonate buffer system especially effective in the body, even though the pKa of carbonic acid is far from normal blood pH?**

- A Because bicarbonate is a strong acid
- B Because the system is "open": CO_2 can be removed by the lungs, shifting equilibrium
- C Because water is the strongest buffer in the body
- D Because hemoglobin destroys all H^+ ions
- E Because bicarbonate can only buffer bases, not acids

5 **If a strong acid is added to blood, the immediate buffer response in the bicarbonate system is best described by:**

- A H^+ combines with HCO_3^- to form H_2CO_3, which can become $CO_2 + H_2O$
- B H^+ combines with CO_2 to form glucose
- C H^+ is pumped directly into red blood cells and disappears
- D H^+ causes bicarbonate to become a stronger base
- E H^+ binds to chloride to form hydrochloric acid gas

6 **Immediately after adding a strong acid to blood (before the lungs and kidneys compensate), which change is most likely?**

- A HCO_3^- decreases and CO_2 increases
- B HCO_3^- increases and CO_2 decreases
- C Both HCO_3^- and CO_2 decrease
- D Both HCO_3^- and CO_2 increase
- E Neither changes because buffers prevent all chemical change

7 **If a strong base is added to blood, which immediate buffer reaction best describes what happens?**

A OH− reacts with H2CO3 to form HCO3− and water

B OH− reacts with bicarbonate to form carbonic acid and water

C OH− is converted into CO2 by carbonic anhydrase

D OH− causes hemoglobin to release oxygen immediately

E Bases cannot be buffered in blood

8 **Blood pH depends strongly on the ratio of bicarbonate to dissolved CO2. Which statement is correct?**

A If both HCO3− and CO2 double, pH must increase

B If both HCO3− and CO2 double, pH stays approximately the same because the ratio is unchanged

C pH depends only on CO2 and not on bicarbonate

D pH depends only on bicarbonate and not on CO2

E pH is independent of all buffers in blood

9 **Which statement BEST explains why CO2 is sometimes called a "volatile acid" in physiology?**

A CO2 is a strong acid that burns tissues

B CO2 can be converted to carbonic acid and then eliminated by exhalation

C CO2 is stored in bones as calcium carbonate

D CO_2 is volatile because it evaporates from blood like alcohol

E CO_2 is produced only in the lungs

10 **Which organ system provides the fastest physiological compensation for a sudden acid load in blood?**

A Liver (by making glycogen)

B Lungs (by changing ventilation and CO_2 removal)

C Kidneys (by changing transporter gene expression within minutes)

D Bones (by growing longer)

E Skin (by sweating out H^+ rapidly)

11 **Which organ system is most important for long-term regulation of blood pH by managing non-volatile acids and bicarbonate levels?**

A Lungs

B Kidneys

C Salivary glands

D Pancreas (via insulin only)

E Skeletal muscle

12 **Which scenario most directly causes metabolic acidosis at a basic level?**

A Hyperventilation during a panic attack

B Diarrhea causing loss of bicarbonate-rich intestinal fluids

C Holding your breath for 2 minutes

D High altitude exposure for 1 hour

E Vomiting stomach acid repeatedly

13 Which scenario most directly causes metabolic alkalosis at a basic level?

A Breathing very fast for several minutes

B Retaining CO2 due to hypoventilation

C Repeated vomiting causing loss of gastric acid (HCl)

D Running hard and producing lactic acid

E Severe diarrhea with bicarbonate loss

14 Which change is most consistent with respiratory acidosis?

A Decreased CO2 due to hyperventilation

B Increased CO2 due to hypoventilation

C Loss of bicarbonate due to diarrhea

D Loss of stomach acid due to vomiting

E Increased bicarbonate due to kidney failure

15 Which change is most consistent with respiratory alkalosis?

A Increased CO2 due to hypoventilation

B Decreased CO2 due to hyperventilation

C Decreased bicarbonate due to diarrhea

D Increased non-volatile acids due to kidney failure

E Loss of bicarbonate due to vomiting

16 **A patient has metabolic acidosis. What is the most expected immediate compensatory response?**

A Hypoventilation to retain CO2 and raise pH

B Hyperventilation to lower CO2 and raise pH

C Kidneys rapidly increase bicarbonate within seconds

D The body stops producing CO2 entirely

E Hemoglobin releases bicarbonate into plasma

17 **A patient has respiratory acidosis due to chronic hypoventilation. Which long-term compensation is most expected?**

A Kidneys increase bicarbonate reabsorption/production and increase H^+ excretion

B Kidneys excrete bicarbonate to fix the low pH

C Lungs begin exhaling oxygen instead of CO2

D Red blood cells stop producing carbonic anhydrase

E Hemoglobin is converted into bicarbonate

18 **A patient has metabolic alkalosis. Which respiratory compensation trend is most expected (even if limited)?**

A Hyperventilation to decrease CO_2

B Hypoventilation to increase CO_2

C No change in ventilation is possible

D Ventilation increases until CO_2 is zero

E Ventilation decreases until oxygen becomes zero

19 **Hemoglobin is considered an important buffer in blood mainly because it can:**

A Convert CO_2 into O_2

B Bind H^+ and reduce free hydrogen ion concentration

C Destroy bicarbonate permanently

D Replace the kidneys in excreting acids

E Prevent CO_2 from entering red blood cells

20 **Which statement about hemoglobin buffering is most accurate?**

A Oxygenated hemoglobin binds H^+ more strongly than deoxygenated hemoglobin

B Deoxygenated hemoglobin tends to bind H^+ more readily, helping buffer acids in tissues

C Hemoglobin cannot bind H^+ because it only binds oxygen

D Hemoglobin buffers by converting H^+ into glucose

E Hemoglobin buffering occurs only in plasma, not in red blood cells

21 **The "chloride shift" in systemic tissues refers to:**

A Cl− leaving red blood cells when oxygen binds to hemoglobin

B HCO_3^- leaving red blood cells into plasma while Cl^- enters to maintain electroneutrality

C Cl^- entering mitochondria to power ATP synthase

D Bicarbonate entering red blood cells only in tissues

E Chloride converting into carbonic acid in plasma

22 **In the lungs, which event best supports CO_2 exhalation based on the bicarbonate system?**

A Bicarbonate exits RBCs so CO_2 stays dissolved in plasma

B Bicarbonate enters RBCs, combines with H^+ to form H_2CO_3, which becomes CO_2 to be exhaled

C Carbonic anhydrase is turned off so CO_2 cannot form

D Hemoglobin releases bicarbonate directly as a gas

E Oxygen is converted into bicarbonate

23 **Which best describes the role of plasma proteins (like albumin) in acid–base balance?**

A They function only as enzymes and do not affect pH

B They act as buffers by accepting or donating H^+ depending on pH

C They directly exhale CO_2 through the skin

D They neutralize acids by becoming glucose

E They replace bicarbonate entirely in blood

24 **Which buffer system is especially important inside cells and in kidney tubules (urine), rather than being the main buffer in plasma?**

A Bicarbonate buffer

B Phosphate buffer ($H_2PO_4^-/HPO_4^{2-}$)

C Sodium chloride buffer

D Glucose buffer

E Oxygen buffer

25 **Which statement BEST distinguishes "buffering" from "compensation" in physiology?**

A Buffering is done by the brain; compensation is done by the heart

B Buffering is immediate chemical binding of H^+; compensation is physiological adjustment by organs (lungs/kidneys) over time

C Buffering changes pH permanently; compensation never changes pH

D Compensation occurs first, then buffering occurs later

E They mean exactly the same thing

26 **Which statement correctly uses the terms acidemia and acidosis?**

A Acidemia is the process; acidosis is the measured low blood pH

B Acidosis is the process that tends to lower pH; acidemia means the blood pH is actually low

C Acidosis and acidemia both mean the same thing: any increase in CO_2

D Acidemia refers only to kidney problems; acidosis refers only to lung problems

E Acidemia means high blood sugar; acidosis means low blood sugar

27 **A student says: "If someone is in acidosis, their blood pH must always be low." What is the best correction?**

A Correct: compensation is impossible in humans

B Incorrect: compensation can bring pH closer to normal even when an acidosis process is present

C Correct: acidosis always means pH below 6

D Incorrect: blood pH never changes in any disease

E Correct: acidosis refers only to low bicarbonate, not to pH

28 **A person suddenly hyperventilates due to anxiety. Which primary acid–base disturbance is most likely first?**

A Metabolic acidosis

B Metabolic alkalosis

C Respiratory alkalosis

D Respiratory acidosis

E No disturbance because breathing cannot affect pH

29 **A person holds their breath for a prolonged time. Which primary acid–base disturbance is most likely first?**

A Respiratory acidosis

B Respiratory alkalosis

C Metabolic alkalosis

D Metabolic acidosis

E No disturbance because CO2 is not related to pH

30 Which statement about where carbonic anhydrase is especially abundant is most accurate?

A It is found only in the lungs, not in blood

B It is abundant in red blood cells and also important in kidney tubule cells

C It is found only in bone marrow to make platelets

D It is found only in mitochondria to run the electron transport chain

E It is found only in the brain for neurotransmitters

31 Why is pure water a poor buffer at physiological pH?

A Because water is not polar

B Because water contains no H^+ ions at all

C Because effective buffers require a weak acid/conjugate base pair at useful concentrations; water's autoionization is minimal at pH ~7

D Because water is a strong base

E Because water reacts only with salts, not with acids

32 **In the bicarbonate buffer system, bicarbonate ($HCO3-$) is best described as the:**

A Strong acid component

B Conjugate base that can accept H^+

C Enzyme that catalyzes $CO2$ breakdown

D Gas that is exhaled by the lungs

E Protein buffer found in hemoglobin

33 **Which statement best describes why exhaling $CO2$ can raise blood pH?**

A Exhaling $CO2$ removes oxygen, which directly increases pH

B Removing $CO2$ shifts the equilibrium away from H^+ production (Le Chatelier's principle), lowering $[H^+]$

C $CO2$ is a base, so exhaling it removes base and raises pH

D Exhaling $CO2$ converts acids into salts in the lungs

E Exhaling $CO2$ increases bicarbonate instantly without any equilibrium

34 **Which blood pH range is considered normal in most physiology references?**

A 6.0–6.5

B 6.8–7.0

C 7.35–7.45

D 7.8–8.2

E 9.0–10.0

35 **A student says: "If CO2 increases, pH should increase too because CO2 is neutral." Which is the best correction?**

A Correct: CO2 cannot affect pH in water

B Incorrect: CO2 reacts with water to form carbonic acid, increasing H^+ and lowering pH

C Incorrect: CO2 directly turns into NaOH, raising pH

D Correct: only kidneys control pH, never lungs

E Incorrect: CO2 is a strong base, so it lowers pH

36 **Which statement correctly matches a primary disturbance with the first variable that changes?**

A Respiratory acidosis: primary fall in bicarbonate

B Metabolic alkalosis: primary rise in bicarbonate (or loss of H^+)

C Respiratory alkalosis: primary rise in bicarbonate

D Metabolic acidosis: primary rise in CO2

E Metabolic acidosis: primary rise in pH

37 **A patient's blood shows low pH and high CO2. The primary disturbance is most likely:**

A Respiratory acidosis

B Respiratory alkalosis

C Metabolic alkalosis

D Metabolic acidosis with full respiratory compensation

E No disturbance; this is normal

38 **A patient's blood shows low pH and low bicarbonate. The primary disturbance is most likely:**

A Metabolic acidosis

B Metabolic alkalosis

C Respiratory alkalosis

D Respiratory acidosis

E Normal physiology

39 **A patient has low pH, low bicarbonate, and low CO2. Which interpretation is best?**

A Primary respiratory alkalosis with renal compensation

B Primary metabolic acidosis with respiratory compensation

C Primary respiratory acidosis with metabolic compensation

D Primary metabolic alkalosis with respiratory compensation

E No acid-base disturbance because two variables are low

40 **A patient has high pH, low CO2, and low bicarbonate. Which interpretation is best?**

A Primary respiratory alkalosis with renal compensation

B Primary metabolic alkalosis with respiratory compensation

C Primary metabolic acidosis with respiratory compensation

D Primary respiratory acidosis with renal compensation

E No disturbance because bicarbonate is low

41 **Which change would most directly increase blood pH (all else equal)?**

A Increase CO_2 while keeping bicarbonate constant

B Decrease CO_2 while keeping bicarbonate constant

C Decrease bicarbonate while keeping CO_2 constant

D Increase H^+ while keeping CO_2 constant

E Increase lactic acid production while keeping ventilation constant

42 **Which change would most directly decrease blood pH (all else equal)?**

A Increase bicarbonate while CO_2 stays constant

B Decrease CO_2 while bicarbonate stays constant

C Increase CO_2 while bicarbonate stays constant

D Decrease H^+ concentration

E Increase ventilation

43 **Which statement about compensation is correct?**

A Compensation always returns pH exactly to 7.40 in all cases

B Compensation can reduce the pH change, but it may not fully normalize pH if the primary problem is severe

C Compensation always changes the same variable that caused the problem

D Only the kidneys can compensate for any acid-base disturbance

E Only the lungs can compensate for any acid-base disturbance

44 During intense exercise, lactic acid production increases. Which immediate blood buffer system helps resist the drop in pH?

A Bicarbonate buffer (and hemoglobin/protein buffers) binding added H^+

B Peptidoglycan buffer in plasma

C Cell wall buffer in red blood cells

D DNA buffer inside the nucleus

E ATP synthase removing H^+ by making ATP in plasma

45 Which statement about kidney action in acid–base balance is MOST accurate at a basic level?

A Kidneys can eliminate CO2 directly by filtration

B Kidneys primarily control blood pH by adjusting H^+ excretion and bicarbonate handling over time

C Kidneys control pH mainly by changing hemoglobin levels

D Kidneys compensate within seconds by changing breathing rate

E Kidneys do not influence blood pH

46 **A student claims: "Bicarbonate is the acid in the buffer system." What is the best correction?**

A Correct: bicarbonate is a strong acid that donates H^+ readily

B Incorrect: bicarbonate is the conjugate base; the acid form is carbonic acid (closely linked to CO_2 in blood)

C Incorrect: bicarbonate is neither acid nor base and does not affect pH

D Correct: bicarbonate is the enzyme that makes CO_2

E Correct: bicarbonate is oxygen dissolved in blood

47 **A patient has metabolic acidosis. Their breathing becomes deep and rapid. Which statement best explains the benefit of this breathing pattern?**

A It increases CO_2 to neutralize acid

B It lowers CO_2, pulling the buffer reaction to consume H^+ and raise pH

C It prevents kidneys from excreting acid

D It increases bicarbonate instantly by secretion from the lungs

E It converts lactic acid into glucose in the alveoli

48 **High altitude often causes hyperventilation. What primary acid–base effect does this tend to cause initially?**

A Respiratory acidosis because oxygen is low

B Respiratory alkalosis because CO_2 is blown off

C Metabolic acidosis because bicarbonate rises

D Metabolic alkalosis because lactic acid rises

E No effect on pH because altitude affects only oxygen, not CO_2

49 **Which statement best links blood buffering to oxygen delivery in tissues (concept level)?**

A When H^+ rises, hemoglobin binds oxygen more tightly, so tissues receive more oxygen

B When H^+ rises (more acidic), hemoglobin tends to release oxygen more easily, supporting oxygen delivery where metabolism is high

C Oxygen delivery is unrelated to CO2 and H^+ in any situation

D Bicarbonate binds oxygen directly, carrying it to tissues

E Only phosphate buffer affects oxygen delivery

50 **Which statement best describes what happens in the lungs that helps remove CO2 from the blood (hard concept, simplified)?**

A Oxygen binding to hemoglobin can promote release of H^+, which helps convert bicarbonate back into CO2 for exhalation

B Oxygen binding to hemoglobin permanently destroys bicarbonate

C CO2 is exhaled because it is filtered by the kidney first

D CO2 is removed mainly by platelets carrying it to the alveoli

E CO2 leaves blood only when blood becomes alkaline, never otherwise

#	Ans	Answer Text
1	C	A solution that resists pH change by containing a weak acid and its conj...
2	B	$CO_2 + H_2O$ H_2CO_3 $H^+ + HCO_3^-$
3	B	Speeds up the conversion between $CO_2 + H_2O$ and H_2CO_3
4	B	Because the system is "open": CO_2 can be removed by the lungs, shifting ...
5	A	H^+ combines with HCO_3^- to form H_2CO_3, which can become $CO_2 + H_2O$
6	A	HCO_3^- decreases and CO_2 increases
7	A	OH^- reacts with H_2CO_3 to form HCO_3^- and water
8	B	If both HCO_3^- and CO_2 double, pH stays approximately the same because th...
9	B	CO_2 can be converted to carbonic acid and then eliminated by exhalation
10	B	Lungs (by changing ventilation and CO_2 removal)
11	B	Kidneys
12	B	Diarrhea causing loss of bicarbonate-rich intestinal fluids
13	C	Repeated vomiting causing loss of gastric acid (HCl)
14	B	Increased CO_2 due to hypoventilation
15	B	Decreased CO_2 due to hyperventilation
16	B	Hyperventilation to lower CO_2 and raise pH
17	A	Kidneys increase bicarbonate reabsorption/production and increase H^+ exc...
18	B	Hypoventilation to increase CO_2
19	B	Bind H^+ and reduce free hydrogen ion concentration
20	B	Deoxygenated hemoglobin tends to bind H^+ more readily, helping buffer ac...
21	B	HCO_3^- leaving red blood cells into plasma while Cl^- enters to maintain e...
22	B	Bicarbonate enters RBCs, combines with H^+ to form H_2CO_3, which becomes C...
23	B	They act as buffers by accepting or donating H^+ depending on pH
24	B	Phosphate buffer ($H_2PO_4^-/HPO_4^{2-}$)
25	B	Buffering is immediate chemical binding of H^+; compensation is physiolog...
26	B	Acidosis is the process that tends to lower pH; acidemia means the blood...
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28	C	Respiratory alkalosis
29	A	Respiratory acidosis
30	B	It is abundant in red blood cells and also important in kidney tubule ce...
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32	B	Conjugate base that can accept H^+
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