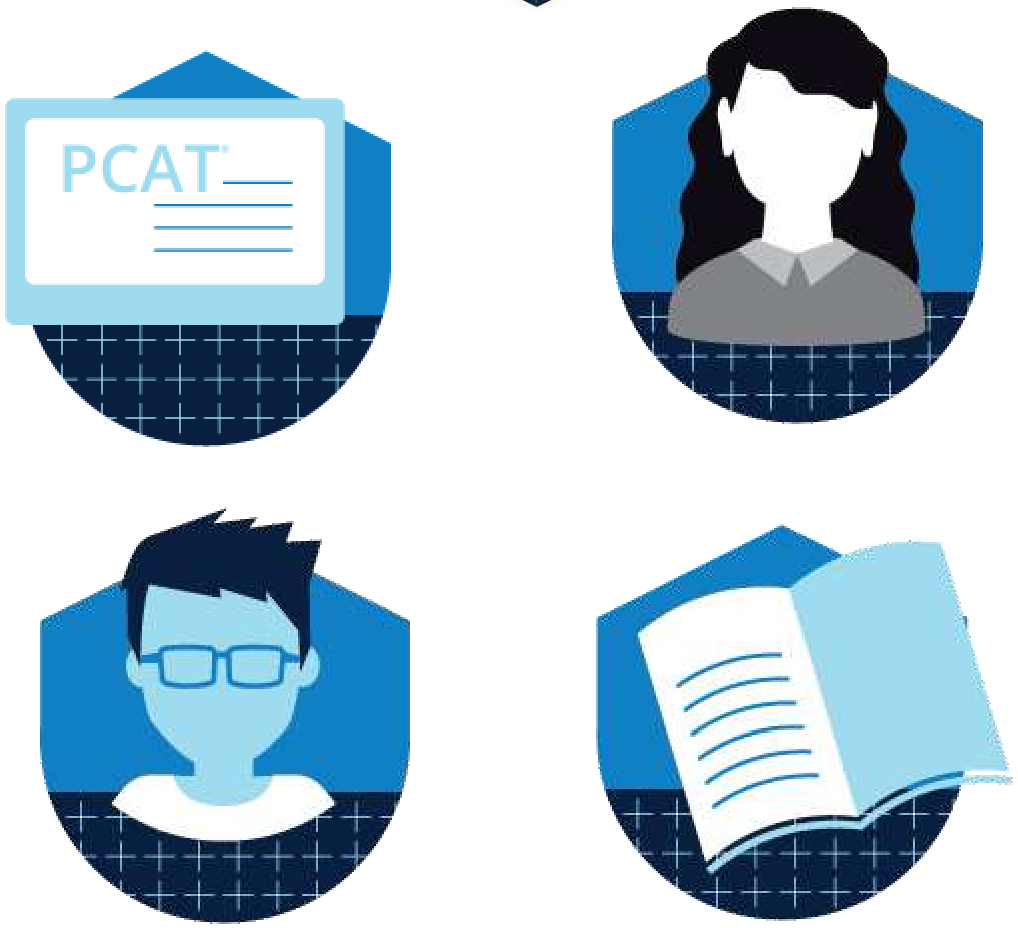
Next Step TEST PREP

PCAT Office Hours: General Chemistry

Today's Agenda

- Welcome to Office Hours!
- Introduction
- Gen Chem Study Strategy
  - Acid-Base Chemistry
  - Solubility
  - Reaction Kinetics
- What Next?



Introduction

Sophia Stone

PCAT Content Manager

- Tutored and taught for 8+ years
- Score 99th percentile on PCAT

Who Is Next Step?

Next Step TEST PREP

- Began in 2009 as a tutoring company
- Focus on graduate admissions tests only
- Team of educational experts
- Helped over 50,000 students in Pre-Health admissions preparation

✓ We never stop improving our materials!

STUDENTS HAVE A CHOICE

Introduction to Office Hours

Thanks for coming to Office Hours!

These sessions are meant to be:

- Interactive
- Problem-focused

✓ Think of a question after Office Hours? Post in our forums at forum.nextsteppcat.com

Getting Started:

1. Turn on your mic
2. Locate the hand-raise button
3. Locate the Question and Chat boxes
4. Let me know if you're having at tech issues!

Gen Chem Study Strategy

Today we're going to focus on maximizing your gen chem performance. Let's reflect on our experiences with chemistry:

- *How do you typically study?*
- *What concepts have been difficult to master?*
- *What formulas and equations give you trouble?*
- *Have you found strategies that work for you?*

Gen Chem Study Strategy

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Connecting the dots

- *How does each topic relate to other gen chem concepts?*
- *What's the big picture?*

Start with the basics

- *Understanding periodic trends, stoichiometry, etc. helps build toward "harder" material*
- *Many students miss questions on "easy" topics*

Review, review, review!

Topic #1: Acid-Base Chemistry

Strong acids to know

p prefix = –log

Acid-Base Chemistry

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How do you find the pH of a strong acid solution?

- *What is the pH of a 1 M solution of H_2SO_4?*

How do you find the pH of a weak acid solution?

- *The K_a of acetic acid is 1.8×10^{-5}. What is the pOH of a 0.05 M solution of acetic acid?*

$$HAc + H_2O \rightarrow Ac^- + H_3O^+$$

Acid-Base Chemistry

K_a = acid dissociation constant

K_b = base dissociation constant

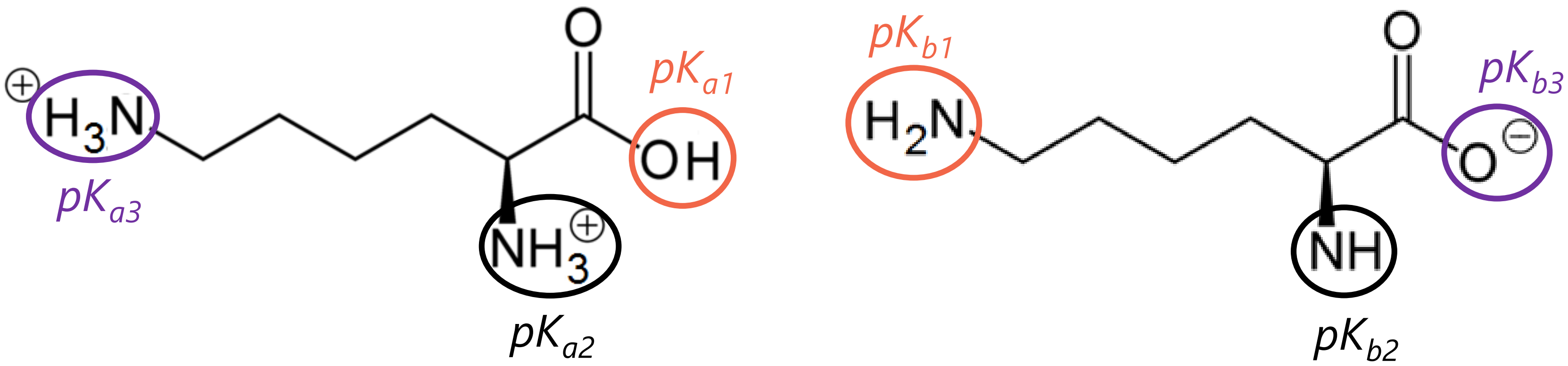
K_w = water ionization constant

What is the expression for the K_b of NH_3?

$K_w = K_a \times K_b$

of acid

of conjugate base



Acid-Base Chemistry

A student combines 50 mL of 0.80 M HF with 40 mL of 0.75 M KOH. The student predicts that the final pH of the solution will be greater than 7. What best explains the observation that a piece of blue litmus paper dipped into the beaker immediately turns red?

A. HF is a strong acid, making the pH of this solution lower than expected.

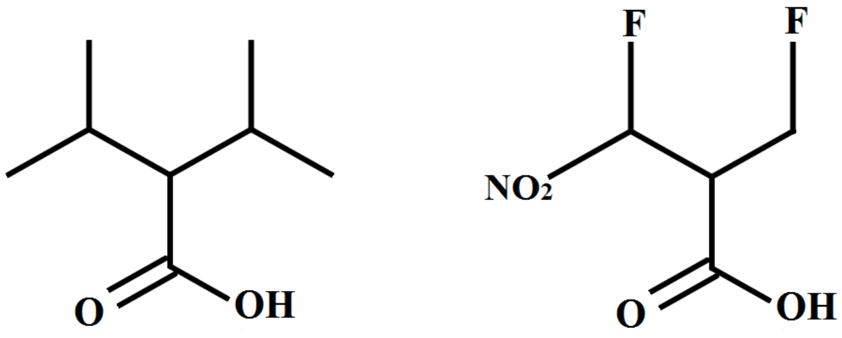
B. Since KOH is strong, it is the pOH of the solution that will be greater than 7, not the pH.

C. pH depends on the concentrations of H^+ and OH^-, regardless of acid and base strength, and the final solution contains more moles of H^+ than OH^-.

D. Blue litmus paper becomes red in basic solution.

Acid-Base Chemistry

The figure below shows two carboxylic acids. The acid with the lower pK_a is:



A. the acid on the left, due to the presence of additional alkyl groups.
B. the acid on the left, due to the stabilizing effects of resonance.
C. the acid on the right, due to the electron-donating substituents.
D. the acid on the right, due to the added inductive effect.

Buffers

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Buffers resist changes in pH. How?

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

- Imagine adding 1 mol HNO_3 to 1 L H_2O.

  Initial pH = 7

  Final pH = –log(1 M) = –log(10^0)

- Now imagine adding 1 mol HNO_3 to a 10 L solution containing 10 mol HCN and 10 mol CN^-.

  weak acid

  conjugate base of the SAME weak acid

  1 mol H^+ → protonates 1 mol CN^-

  pH hardly changes!

- When $[A^-] > [HA]$:
- When $[A^-] < [HA]$:
- When $[A^-] = [HA]$:

Buffers

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For carbonic acid, $K_{a1} = 4.3 \times 10^{-7}$ and $K_{a2} = 5.6 \times 10^{-11}$. What is the pH of a solution made with equimolar amounts of sodium bicarbonate and potassium carbonate?

A. 5.6
B. 6.37
C. 10.25
D. 11.44

The pK_a of hydrofluoric acid is 3.14. What is the pH of a solution made by mixing 3 L of a 1.5 M solution of HF with 1 L of a 2.25 M solution of NaOH?

A. 1.50
B. 2.14
C. 3.14
D. 4.14

Titrations

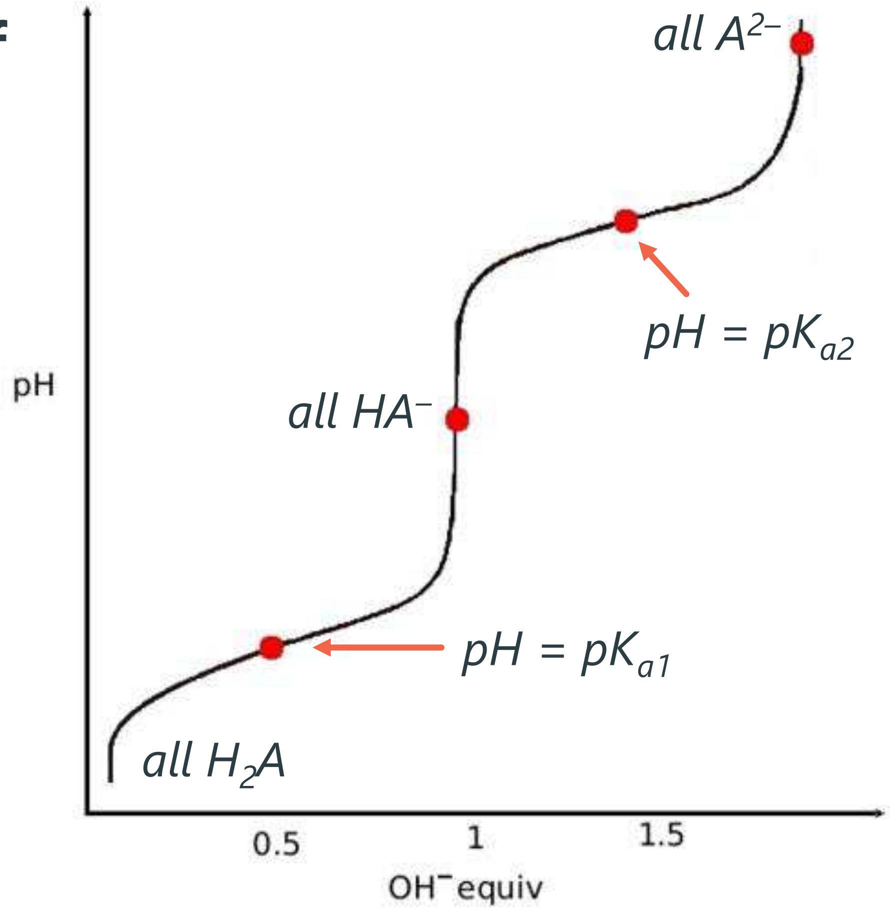
Titrations are used to measure the concentration of an unknown acid or base.

- Analyte = solution of unknown concentration
- Titrant = acid or base of known concentration

Understand the difference between an equivalence point and a half-equivalence point!

- mol original acid = mol conjugate base at…
- mol original acid = mol base added at…

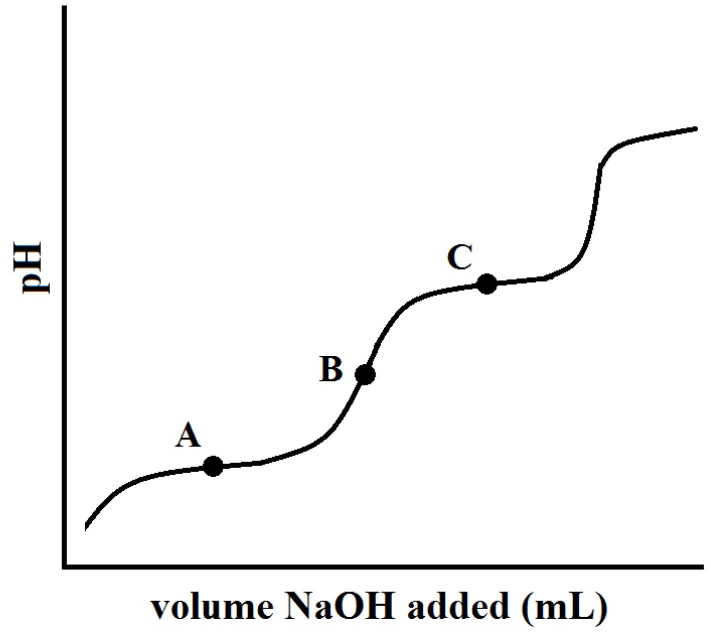
Imagine beginning with 1 L of 1 M H_2SO_4.



Titrations

Suppose 0.75 M H_2CO_3 is titrated with 2.25 M NaOH to generate the following titration curve. If the initial volume of H_2CO_3 was 500 mL, what volume of NaOH is required to reach point A on the curve?

A. 83 mL
B. 166.5 mL
C. 333 mL
D. 1000 mL



Topic #2: Solubility

K_{sp} = solubility product

- *What factors affect K_{sp}?*
- *What factors do not change K_{sp}?*

Q = ion product (NOT at equilibrium)

- If $Q < K_{sp}$, solid will dissolve more
- If $Q = K_{sp}$, at equilibrium
- If $Q > K_{sp}$, solid will precipitate

Molar solubility = moles of solute that can dissolve in 1 L solvent

- Suppose AgCl dissolves in water.

$$AgCl\ (s) \rightarrow Ag^{+}\ (aq) + Cl^{-}\ (aq)$$

$$K_{sp} = [Ag^{+}][Cl^{-}]$$

Solubility

The K_{sp} of zinc phosphate is 9.0×10^{-33}. An organic chemistry student, adds 0.01 mol of Na_3PO_4 to a solution of 0.0002 mol $Zn(NO_3)_2$ in 2 L of water. Will the student see a solid precipitate?

A. Yes, because the ion product is less than the K_{sp} of zinc phosphate.

B. Yes, because the ion product exceeds the K_{sp} of zinc phosphate.

C. No, because the ion product is less than the K_{sp} of zinc phosphate.

D. No, because zinc phosphate is a soluble salt.

Calcium oxalate, a salt found in large amounts in kidney stones, dissociates according to the equilibrium below.

$$CaC_2O_{4\,(s)} \leftrightarrow Ca^{2+} + C_2O_4^{2-}$$
$$K_{sp} = 2.7 \times 10^{-9}$$

If 5 moles of calcium oxalate are added to 1 L of distilled water, what concentration of oxalate ion will exist in solution?

A. 2.7×10^{-9} M
B. 5.2×10^{-5} M
C. 2.6×10^{-4} M
D. 1.7×10^{-3} M

Reaction Kinetics

The reaction below depicts a theoretical chemical process that is being studied by a university aeronautics lab. What is the rate law for this reaction?

$$5X + 2Y \rightarrow 3Z$$

A. Rate = $\frac{Z^3}{X^5Y^2}$

B. Rate = k[5X][2Y]

C. Rate = k[X]5[Y]^2

D. This answer cannot be determined with the information given.

A mixture of reagents K, L, and M react in one bimolecular step to yield product P. The rate law for this reaction CANNOT be:

A. rate = k[K][L].

B. rate = k[M]^2.

C. rate = k[L][K][M].

D. rate = [L][M].

Topic #3: Reaction Kinetics

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Reaction rate = $k[A]^n$

- Zero order = k
- First order = k[A]
- Second order = $k[A]^2$ or k[A][B]

Trial	[A]	[B]	Reaction Rate
1	100	100	1
2	200	100	2
3	100	400	16

A + B → C

- Rate = k[A][B]? *Not necessarily!*
- Rate = $k[A]^m[B]^n$ ***m** and **n** must be experimentally determined*

Trial 1 vs. Trial 2:

- [A] ↑ 2x, [B] constant → rate ↑ 2x $2^1 = 2$
- Rate = $k[A]^1[B]^n$

Trial 1 vs. Trial 3:

- [A] constant, [B] ↑ 4x → rate ↑ 16x $4^2 = 16$
- Rate = $k[A]^1[B]^2$

Multistep Reactions

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A + B → C

- Step 1: A + B → Y
- Step 2: Y → C

rate-determining step
(determines overall rate)

Rate = $k_2[Y]^2$

Reaction Kinetics

Consider the following multistep reaction:

$$2\,A \rightarrow D$$

- Step 1: $A + A \rightarrow B$ k_1
- Step 2: $B \rightarrow C$ k_2
- Step 3: $C \rightarrow D$ k_3

If the unimolecular steps are extremely fast, what is the rate law for the overall reaction?

A. Rate = $k[A][B]$

B. Rate = $k_1[A]^2$

C. Rate = $k_1k_2k_3[A][B]^2[C]$

D. Rate = $k_1k_3[A][C]$

Reaction Kinetics

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The following questions rely on the table below.

Trial	[A] (mM)	[B] (mM)	[C] (mM)	Rate (mM/s)
1	0.5	1.0	1.0	0.004
2	2.0	1.0	1.0	0.016
3	0.5	3.0	1.0	0.036
4	0.5	1.0	2.0	0.004

Based on the experimental data in the table above, determine the rate law for this reaction.

A. Rate = $k[A]^2[B][C]$
B. Rate = $k[A][B]^3$
C. Rate = $k[A][B]^2[C]$
D. Rate = $k[A][B]^2$

In a fifth trial, the initial concentrations of A, B, and C are 2 mM, 4 mM, and 0.5 mM, respectively. The initial rate of the reaction will be:

A. 0.064 mM/s.
B. 0.256 mM/s.
C. 0.512 mM/s.
D. 32 mM/s.

Difficult Passage

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An introductory chemistry laboratory involved the study of various reactions that produced precipitates when aqueous solutions were combined. Students were given a total of nine different solutions in dark brown glass bottles and asked to mix equal portions of these solutions in reaction wells, using pipets. The students were asked to record their observations for appropriate combinations in tabular form, including formation of precipitates, bubbling, color changes or any other observations they thought were relevant.

One of the student's results is shown in Table 1. In order to prevent any hydrolysis of the Cu^{2+} or Fe^{3+} ions, the professor added a small amount of acid to these two solutions. The professor asked the students to perform some of these reactions in a fume hood to prevent being exposed to potentially noxious fumes. The professor noted that the dark brown bottles can help prevent reactions with light common to transition metals in the fifth period and below.

Difficult Passage

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Table 1. Observations related to mixing known aqueous solutions. NR stands for "no reaction".

	$NaCl$ colorless	$NaOH$ colorless	Na_2S colorless	Na_2CO_3 colorless
KNO_3 colorless	NR	NR	NR	NR
$AgNO_3$ colorless	White precipitate	Beige precipitate	Black precipitate	White precipitate
$Ca(NO_3)_2$ colorless	NR	White precipitate	White precipitate	White precipitate
$Cu(NO_3)_2$ blue	NR	Pale blue gel	Black precipitate	Blue-green precipitate
$Fe(NO_3)_3$ orange	NR	Orange gel	Black precipitate	Orange precipitate

Difficult Passage

Subsequently, the students were given an unknown solution in test tubes. The students were told that the unknown contained two of the solutions used in the first part of the experiment. The students were also told that the unknown solution would always contain sodium nitrate. It was the student's job to identify the other ions present in the unknown by reacting the unknown solution with the known solutions and comparing their results to the previously obtained results.

Student A was given 20 mL of a colorless unknown solution. Unfortunately, this student ran out of the unknown solution and had to ask the professor for additional solution. Surprisingly to this student, silver nitrate was the only solution that caused the formation of a precipitate with the unknown. Student A correctly reported the ions present in the unknown solution to the professor.

Student B was given 20 mL of an orange unknown solution. This student reacted this unknown with a small amount of only one of the known solutions and found that no precipitate formed. Having identified the ions present in the unknown solution, Student B reported her results to the professor.

Difficult Passage

What is the formula of the precipitate formed by combining the iron (III) nitrate solution with the sodium sulfide solution?

A. FeS
B. FeS_2
C. Fe_2S_3
D. Fe_3S_2

In aqueous solution Fe^{3+} will undergo a hydrolysis reaction to form an orange gelatinous precipitate. Which of the following reactions best describes the formation of this precipitate?

A. Fe^{3+} (*aq*) → $FeOH^{2+}$ (*s*) + H^+ (*aq*)
B. $Fe3^+$ (*aq*) → $Fe(OH)_3$ (*s*) + 3 H^+ (*aq*)
C. Fe^{3+} (aq) + NO_3^- (aq) + 2 H^+ (*aq*) → $Fe(OH)_2$ (*s*) + NO (*g*)
D. Fe^{3+} (*aq*) + 2 H_2O (*l*) → $Fe(OH)_2$ (*s*) + H_2 (*g*)

Difficult Passage

When the copper (II) nitrate and iron (III) nitrate solutions were reacted with the sodium carbonate solution, some bubble formation was observed by certain students. What was the most likely identity of the bubbles?

A. Carbon dioxide
B. Carbon monoxide
C. Elemental nitrogen
D. Nitrogen monoxide

Student C was given an unknown wrapped in aluminum foil. The student asked the professor why his unknown was the only one wrapped in aluminum foil and the professor responded, "To prevent light from causing an unwanted side reaction". Which of the following was most likely in the unknown solution?

A. Copper (II) nitrate, because exposure to light causes the solution to turn blue.
B. Silver nitrate, because exposure to light can cause the formation of a black precipitate of elemental silver.
C. Sodium sulfide, because exposure to light cause the formation of the smell of rotten eggs.
D. Sodium carbonate, because exposure to produces carbon dioxide gas.

Q&A

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4.7

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One-on-One Tutoring

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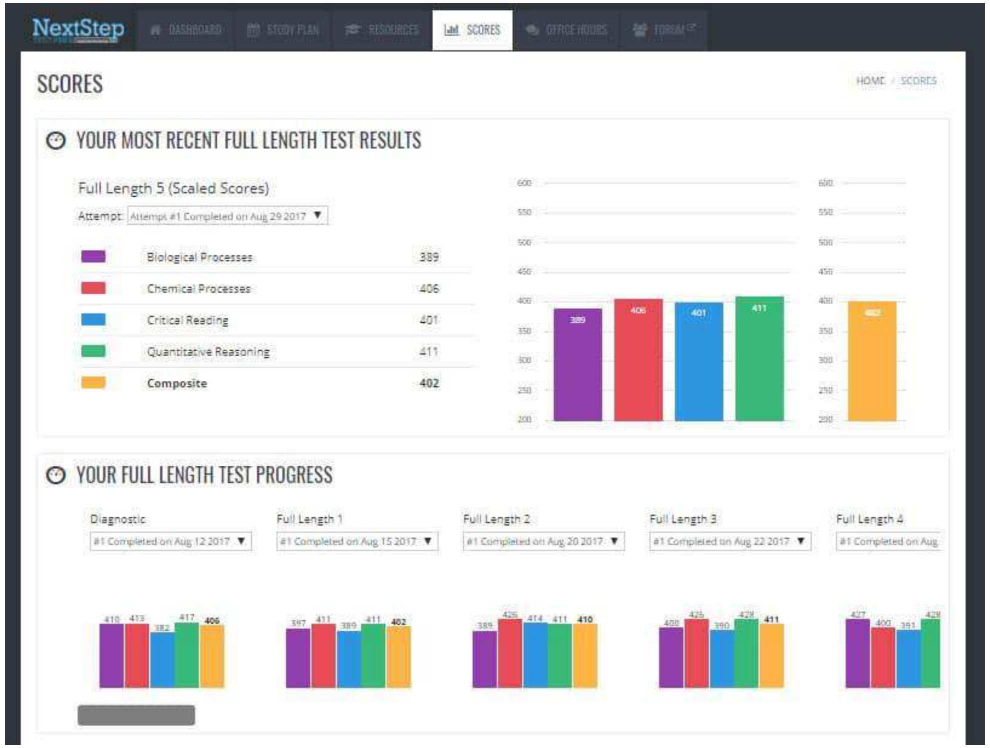

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- ✓ Prepping early ensures you'll be ready for exam day!