Next Step MCAT Super Review: Electrochemistry

- Welcome to Super Review!
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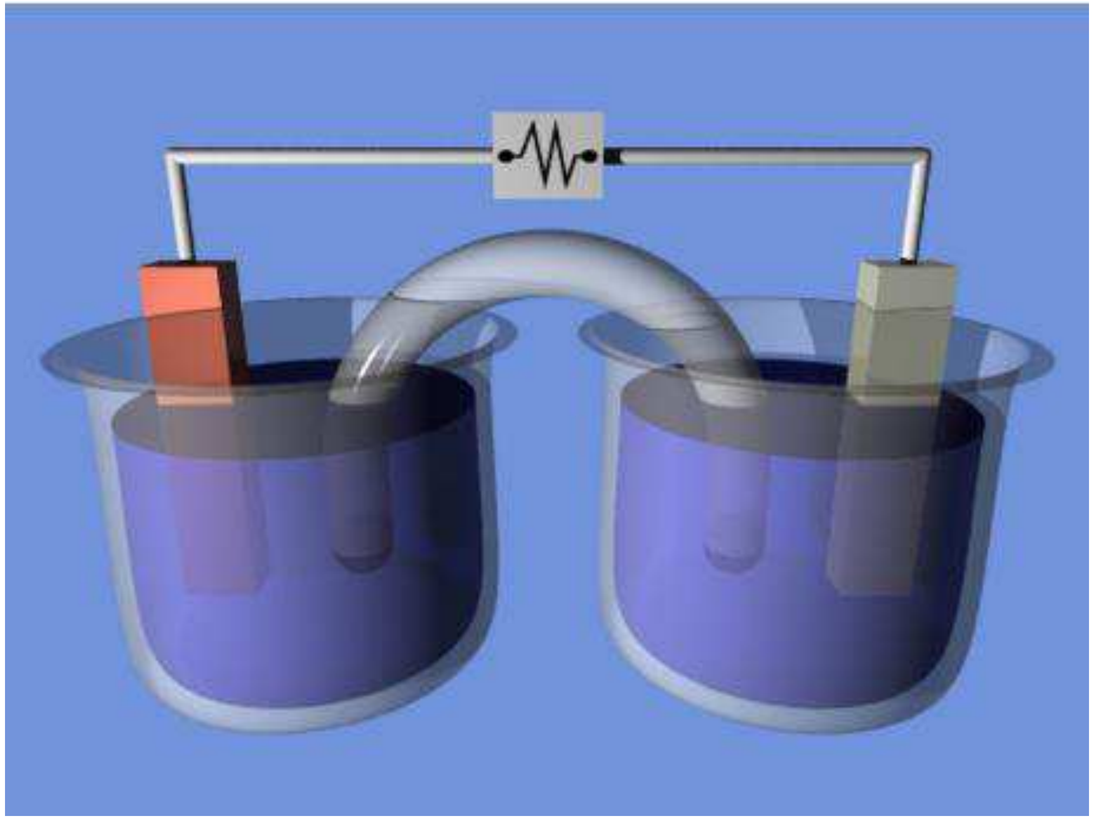
- What Next? How Can Next Step Help?
- Q & A



Introduction to Super Review

- **Thanks for coming to Next Step Super Review!**
- **Here's how it works…**
- **These sessions are meant to be:**
  - **Interactive**
  - **Problem-focused**
  - **Specific to your needs (*so ask questions!*)**
- **Today's focus: review of amino acids**
- **This is NOT a lecture! You can benefit most by:**
  - **Raising your hand and speaking**
  - **Commenting in the Question/Chat box**
  - **Participating!**

Before Getting Started

1. **If you have a microphone, make sure it is turned on and easily available.**
2. **Locate the hand-raise button on the toolbar on your screen.**
3. **Locate the Question box on the toolbar.**
4. **Let me know if you're having any technical issues!**

If on wireless connection:

- **Close any other internet resource-heavy processes**
- **Ask other users on network to do same**
- **Sit as close to router as possible**

Gen Chem Study Strategy

While everyone learns differently, some tactics can help virtually any student master chemistry.

“Connecting the dots”

Try not to think of each topic (acid-base chem, equilibrium, etc.) as a separate entity!

Instead, ask yourself:

- *How does this topic relate to other general chem concepts?*
- *What relevance might this topic have to orgo, biochemistry, etc.?*

Can you think of a biochem topic that relates to general chemistry?

Don’t count any topic out

Understanding periodic trends, stoichiometry, etc. is necessary to properly grasp “harder” material

Many students miss more questions on “easy” topics than on “difficult” ones, like electrochemistry!

Review, review, review – and get to know your weaknesses!

Predicting reduction and oxidation

- Reduction – gain of electrons
  - $Cu^{2+} + 2e^- \rightarrow Cu\ (s)$
- Oxidation – loss of electrons
  - $Na\ (s) \rightarrow Na^+ + e^-$
- But how can we tell what will reduce / oxidize?
  - Use reduction / oxidation potentials
  - More + = *more favorable*
  - More - = *more unfavorable*

Half-reaction	E° (V)
$Ag^+ + e^- \rightarrow Ag\ (s)$	+0.80
$Cu^{2+} + 2\ e^- \rightarrow Cu\ (s)$	+0.34
$2\ H^+ + 2\ e^- \rightarrow H_2\ (g)$	0.00
$K^+ + e^- \rightarrow K\ (s)$	-2.92

Half-reaction	E° (V)
$K\ (s) \rightarrow K^+ + e^-$	+2.92
$H_2\ (g) \rightarrow 2\ H^+ + 2\ e^-$	+0.00
$Cu\ (s) \rightarrow Cu^{2+} + 2\ e^-$	-0.34
$Ag\ (s) \rightarrow Ag^+ + e^-$	-0.80

Oxidizing / reducing agents

- Consider this reaction: $NiSO_4$ + Ag (s) → $AgSO_4$ + Ni (s)
- What is the oxidizing agent? *(NOT the species that becomes oxidized)*

$Ag(s) \rightarrow Ag^{+} + e^{-}$

oxidizes Ag

$Ni^{2+} + 2e^{-} \rightarrow Ni(s)$

- Oxidizing agent = *oxidant*
- Reducing agent = *reductant*

Example – predicting redox reactions

- Considering this table….
  - Best oxidizing agent?
  - Best reducing agent?
- What will be the E° when Ag^+ reacts with Zn (s)?
  - Easy way to do this – just add up half-reactions!

Half-reaction	E° (V)
$Cl_2 + 2 e^- \rightarrow 2 Cl^-$	+1.36
$Ag^+ + e^- \rightarrow Ag$ (s)	+0.80
$Cu^{2+} + 2 e^- \rightarrow Cu$ (s)	+0.34
$2 H^+ + 2 e^- \rightarrow H_2$ (g)	0.00
$Zn^{2+} + 2 e^- \rightarrow Zn$ (s)	-0.76
$^+ + e^- \rightarrow K$ (s)	-2.92

$Ag^+ + e^- \rightarrow Ag$ (s)	+0.80

$Zn^{2+} + 2 e^- \rightarrow Zn$ (s)	-0.76

→

Zn (s) $\rightarrow Zn^{2+} + 2 e^-$	+0.76

0.80 V + 0.76 V = 1.56 V

We will have some great free resources and discounts available for you at the end of the presentation. Stick around and give us some feedback on our short survey as well!

MCAT Questions: Reduction/Oxidation

8. Na^+ has a reduction potential of -2.71, while Mg^{2+} has a reduction potential of -2.38. Which metal serves as the better reducing agent?

A) Na^+, because it is more prone to gaining electrons.
B) Mg^{2+}, because it is more prone to gaining electrons.
C) Na(s), because it more readily gives up electrons.
D) Mg(s), because it more readily gives up electrons.

9. From the data on the right, the best oxidizing and reducing agents, respectively, are:

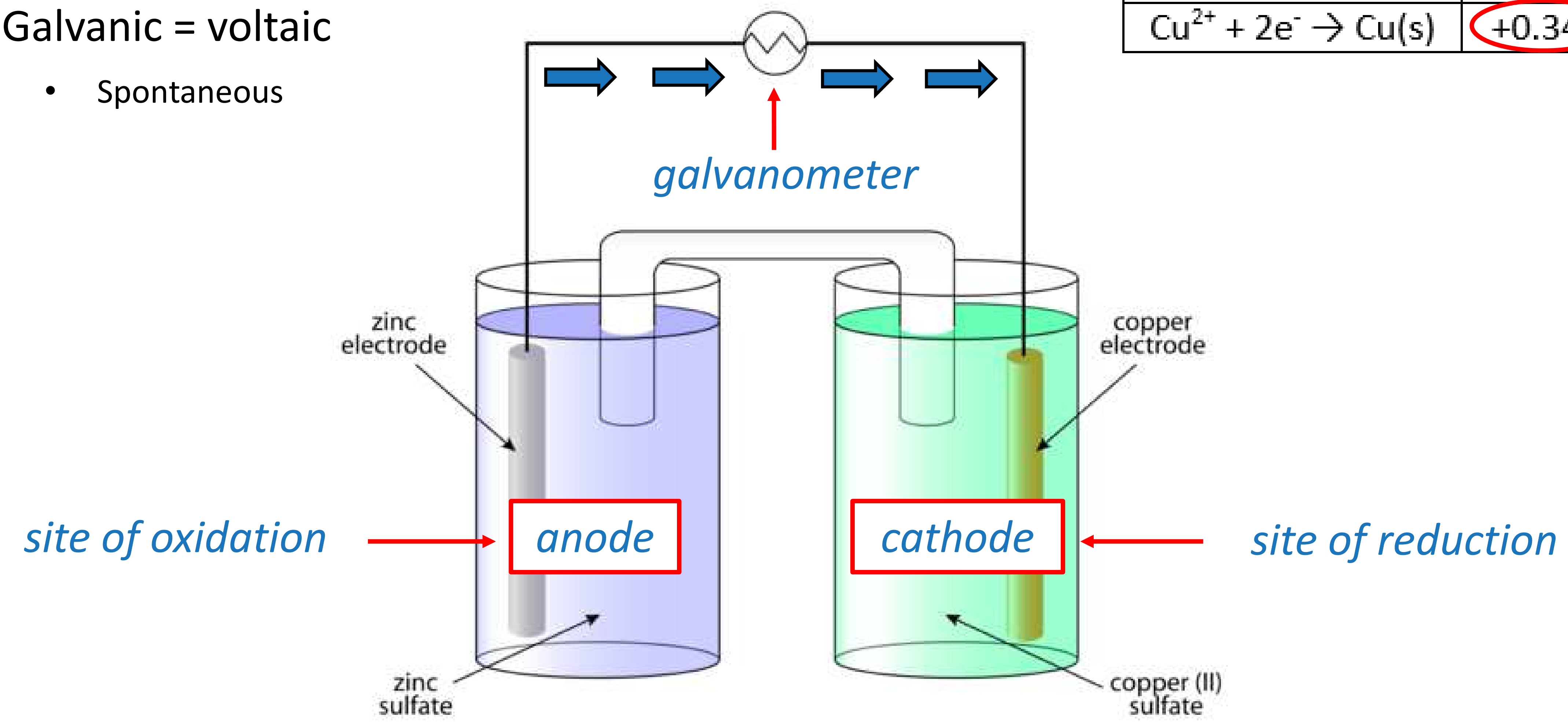
A) Na (s) and Cl_2 (g).
B) Cl_2 (g) and Na (s).
C) Na^+ and Cl^-.
D) Cl^- and Na^+.

Half-reaction	E° (volts)
$Na^+ + e^- \rightarrow Na$ (s)	-2.71
$Al^{3+} + 3e^- \rightarrow Al$ (s)	-1.66
$Zn^{2+} + 2e^- \rightarrow Zn$ (s)	-0.76
$Cd^{2+} + 2e^- \rightarrow Cd$ (s)	-0.40
$2H^+ + 2e^- \rightarrow H_2$ (g)	0.00
$Cu^{2+} + 2e^- \rightarrow Cu$ (s)	0.34
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	0.77
Cl_2 (g) $+ 2e^- \rightarrow 2Cl^-$	1.36

Galvanic cells – what are they?

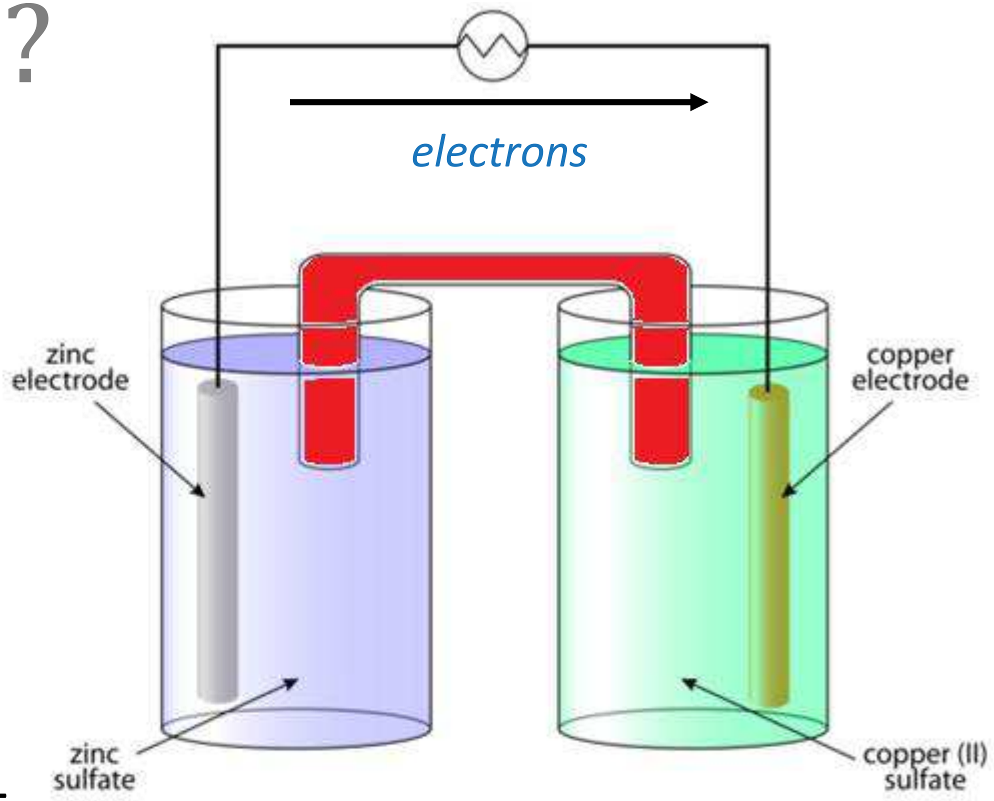
Reaction	E°
$Zn^{2+} + 2e^- \rightarrow Zn(s)$	-0.76
$Cu^{2+} + 2e^- \rightarrow Cu(s)$	+0.34

- Galvanic = voltaic
  - Spontaneous



But what about this structure?

- Salt bridge
- If it weren't present….
  - → - charge would build up on the cathode
  - → + charge would build up on the anode
  - → reaction would stop prematurely
- Electrolytes that move across bridge can be + or -
  - Which way would + move?
  - Which way would - move?



MCAT Question: Galvanic Cells

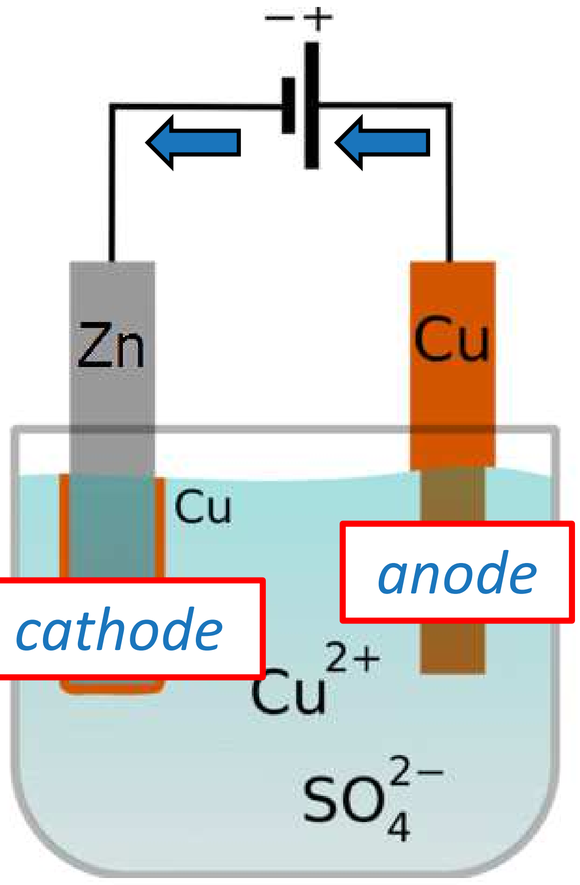
10. The oxidation potentials of Na (s), Cd (s), and Ni (s) are +2.71, +0.40, and +0.28, respectively. A student sets up a galvanic cell with a cadmium anode and a nickel cathode under standard conditions. If he wished to make the cell potential of this apparatus more positive, which change should he implement?

A) He could replace the cadmium anode with solid sodium metal in aqueous solution.
B) He could increase the concentration of Ni^{2+}.
C) He could increase the concentration of Cd^{2+}.
D) Given the information above, a galvanic cell could not have a Cd anode and a Ni cathode.

Switching it up: electrolytic cells

- Electrolytic → *nonspontaneous*

Reaction	E°
$Zn^{2+} + 2e^- \rightarrow Zn(s)$	-0.76
$Cu^{2+} + 2e^- \rightarrow Cu(s)$	+0.34



site of reduction → cathode

anode ← *site of oxidation*

Charge conventions

- In a galvanic cell: ⊖ ⊕
  - electrons spontaneously move from anode to cathode

- In an electrolytic cell: ⊕ ⊖
  - electrons nonspontaneously move from anode to cathode

Worked example: electrochem math

- A chemistry professor is attempting to plate the metal cathode of an electrolytic cell with copper, using a solution of $CuSO_4$. If the cell sustains a current of 4 A for 8 minutes, what mass of Cu will be plated?

$$4\ A = 4\ C/s$$

$$8\ min \times (60\ s / min) = 480\ s$$

$$4\ C/s \times 480\ s = 1920\ C$$

$$\text{Faraday's constant} = 96{,}487\ C / mol\ e^-$$

$$1920\ C \times 1\ mol\ e^- / 10^5\ C = 1.92 \times 10^{-2}\ mol\ e^-$$

Worked example: electrochem math

- A chemistry professor is attempting to plate the metal cathode of an electrolytic cell with copper, using a solution of $CuSO_4$. If the cell sustains a current of 4 A for 8 minutes, what mass of Cu will be plated?

$$1.92 \times 10^{-2} \text{ mol } e^-$$

$$Cu^{2+} + 2e^- \rightarrow Cu\ (s)$$

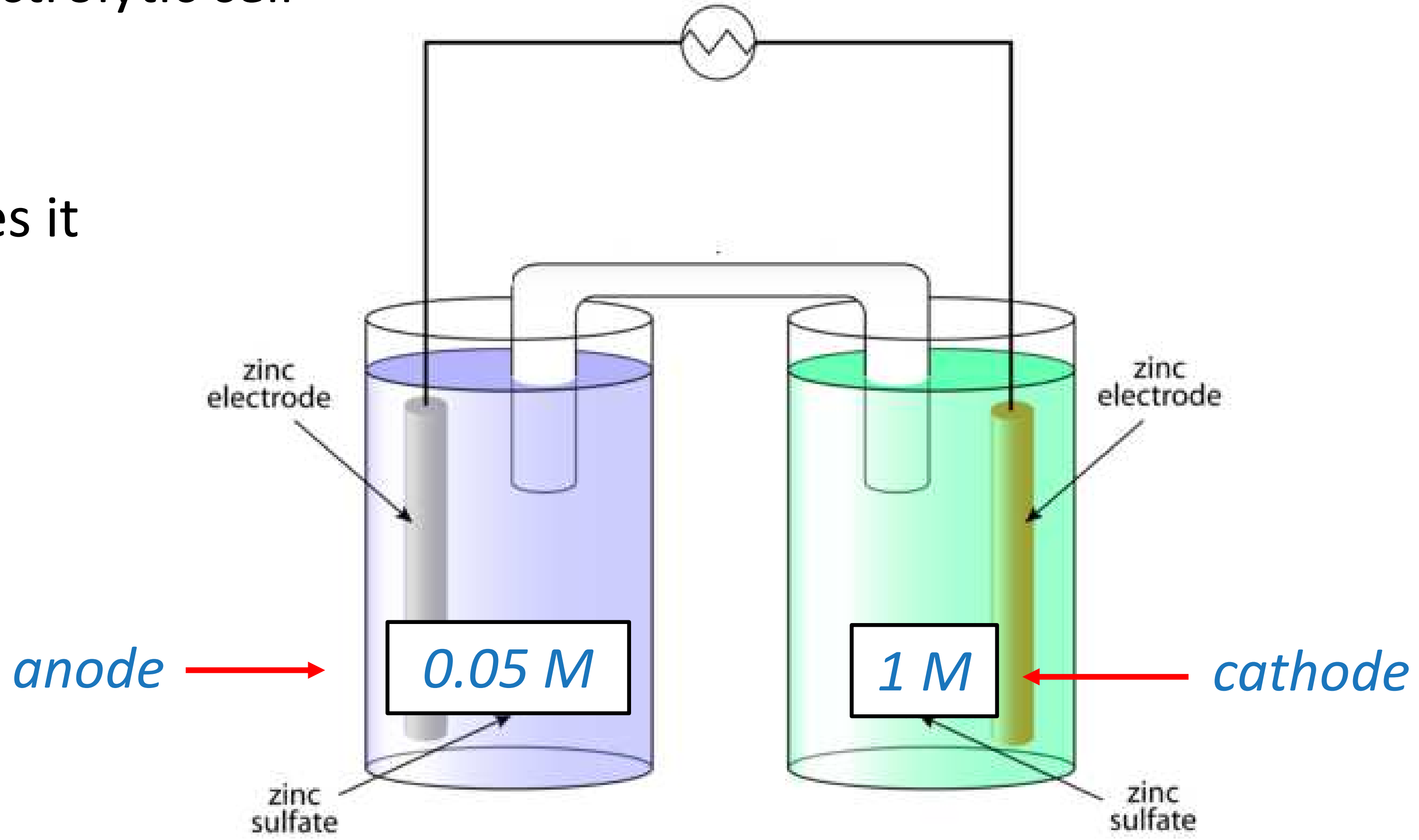
$$1.92 \times 10^{-2} \text{ mol } e^- \times (1 \text{ mol Cu}) / (2 \text{ mol } e^-) = 0.96 \times 10^{-2} \text{ mol Cu}$$

$$0.96 \times 10^{-2} \text{ mol Cu} \times (63.5 \text{ g Cu}) / (1 \text{ mol}) = \boxed{0.61 \text{ g Cu}}$$

Concentration cells

Reaction	E°
$Zn^{2+} + 2e^- \rightarrow Zn(s)$	-0.76
$Zn(s) \rightarrow Zn^{2+} + 2e^-$	+0.76

- Type of galvanic / electrolytic cell
- E° = 0 V
- But if E° = 0, how does it work?



You can use these equations!

- Nernst equation (simplified)
  - $\uparrow$ Q = $\downarrow$ E
  - $\downarrow$ Q = $\uparrow$ E
  - Also has biological uses!

$$E = E° - \frac{0.0591}{n} \log Q$$

no need to memorize!

- Other equations

$$\Delta G° = -nFE°_{cell}$$

$$\Delta G° = -RT \ln K$$

MCAT Practice Passage

Experiments with static electricity and the triboelectric effect revealed the relationship between electrical conduction and muscle activity. While removing the skin of the frog, a scalpel that had been electrically charged touched muscle, and the frog spontaneously moved as if it had come back to life. Investigations into this "animal electricity." Showed that tissue not only responded to electrical stimulation, but was also a conductor of charge.

Further experiments demonstrated this phenomenon was not limited to animal tissue. For instance, soaking a paper towel in an electrolytic solution allowed for conduction of electricity when placed in contact with different metals.

Scientists eventually were able to rank various metals to create the first electrochemical series (Table 1), and associated electromotive forces, based on the idea that various electrodes have a potential to cause charges to move in a conducting material. Subsequently, a mathematical relationship (Equation 1) was developed to predict the potentials for electrochemical cells:

$$E = E° - (RT/nF) \ln Q \qquad \textbf{Equation 1}$$

where R = 8.314 J K-1 mol-1, T is the absolute temperature, n is the moles of electrons in the balanced reaction and F is Faraday's constant.

MCAT Practice Passage

Table 1 Select Standard Reduction Potentials

Reduction Half-Reaction	E° (V)
F_2 (g) + 2 e^- → 2 F^- (aq)	+2.87
MnO_4^- (aq) + 8 H^+ (aq) + 5 e^- → Mn^{2+} (aq) + 4 H_2O (l)	+1.51
$Cr_2O_7^{2-}$ (aq) + 14 H^+ (aq) + 6 e^- → 2 Cr^{3+} (aq) + 7 H_2O (l)	+1.33
O_2 (g) + 4 H^+ (aq) + 4 e^- → 2 H_2O (l)	+1.23
Ag^+ (aq) + e^- → Ag (s)	+0.80
O_2 (g) + 2 H_2O (l) + 4 e^- → 4 OH^- (aq)	+0.40
Cu^{2+} (aq) + 2 e^- → Cu (s)	+0.34
2 H^+ (aq) + 2 e^- → H_2 (g)	0.00
Ni^{2+} (aq) + 2 e^- → Ni (s)	−0.28
Cd^{2+} (aq) + 2 e^- → Cd (s)	−0.40
Zn^{2+} (aq) + 2 e^- → Zn (s)	−0.76
2 H_2O (l) + 2 e^- → H_2 (g) + 2 OH^- (aq)	−0.83
Li^+ (aq) + e^- → Li (s)	−3.05

MCAT Practice Passage

11. An electrochemical cell is built around on the following redox reaction at 25°C:

$$Cu^{2+} (aq) + Zn (s) \rightarrow Zn^{2+} (aq) + Cu (s)$$

What is the cell potential when the concentration of Cu^{2+} is 10^8 times greater than the concentration of Zn^{2+}?

A. -0.18 V
B. 1.10 V
C. 1.34 V
D. 1.57 V

12. According to Table 1, which species is the best oxidizing agent?

A. MnO_4^- (aq)
B. $Cr_2O_7^{2-}$ (aq)
C. Zn (s)
D. Li (s)

MCAT Practice Passage

13. Which of the following is NOT equivalent to electrical potential?

A. A•Ω
B. W/A
C. J/C
D. Kg•m/s^2

14. Which of the following statements is true concerning a galvanic cell with a positive potential?

I. The redox reaction is nonspontaneous because the Gibbs free energy is positive.
II. Electrons flow through the circuit from the anode to the cathode.
III. The anode is negatively charged.

A. I only
B. II only
C. I and II only
D. II and III only

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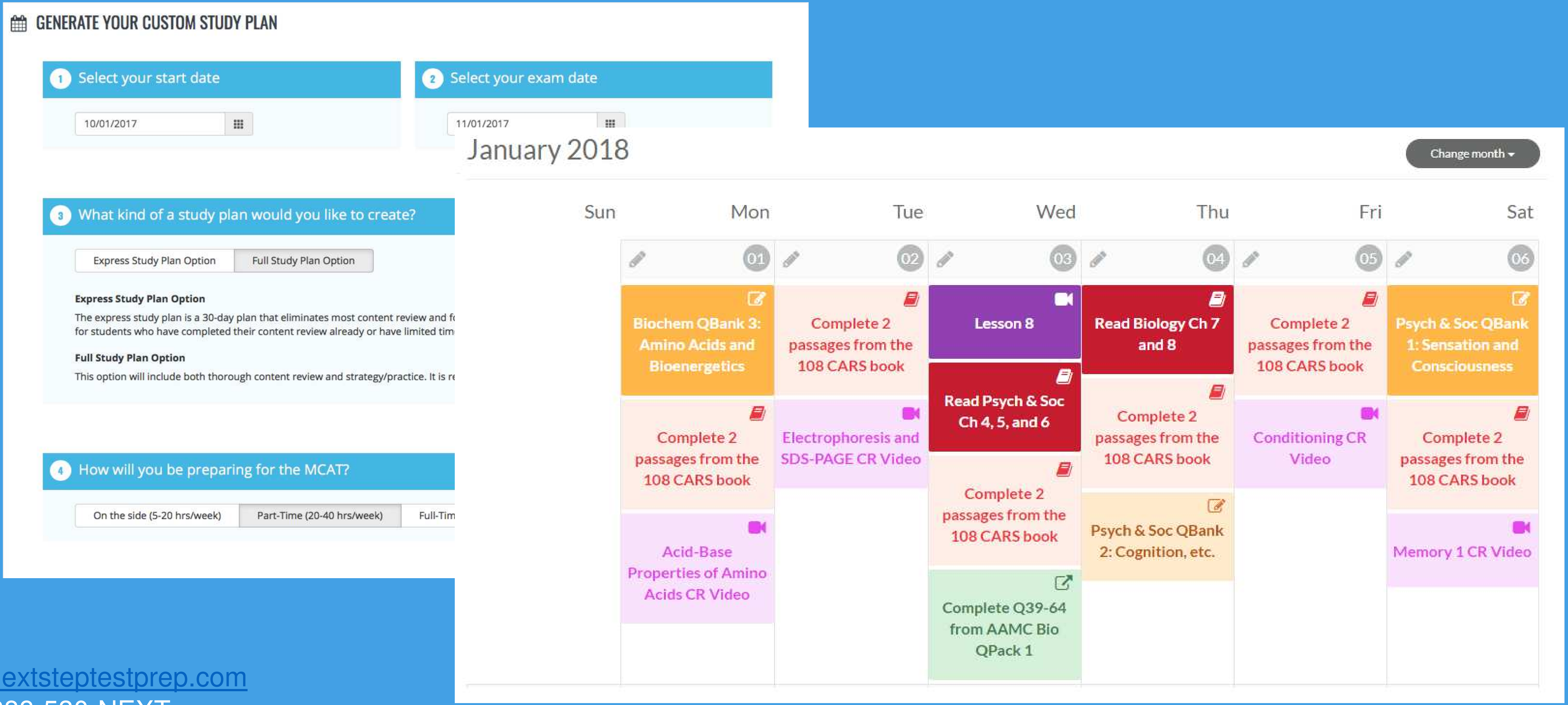

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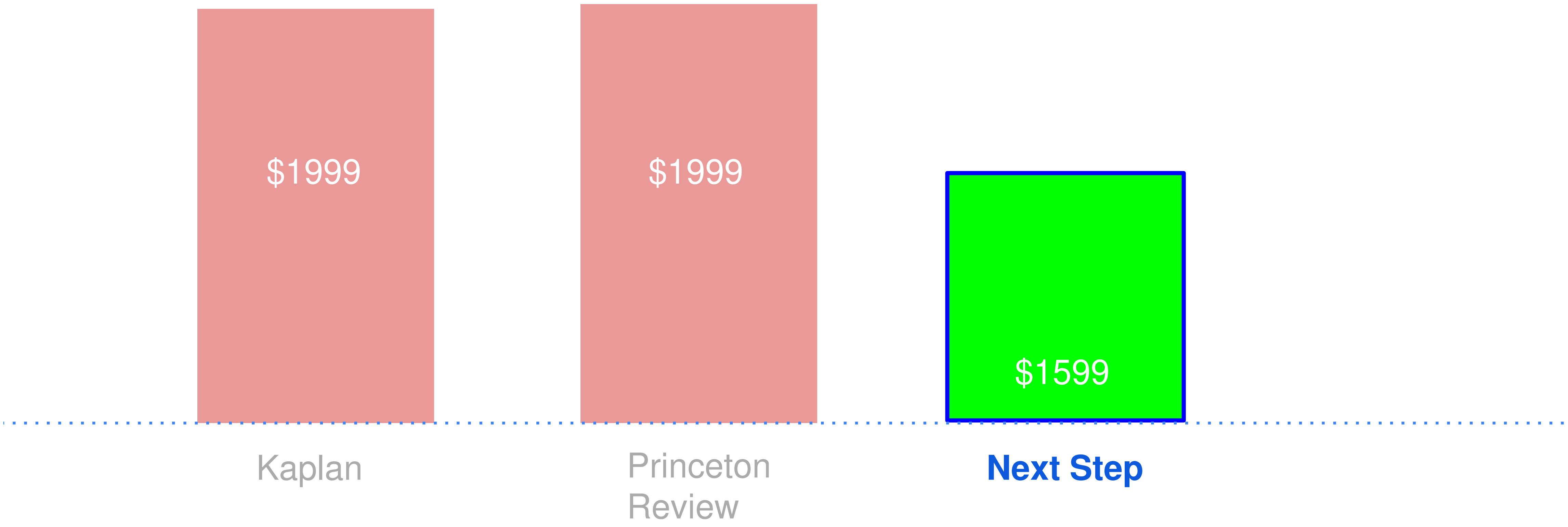

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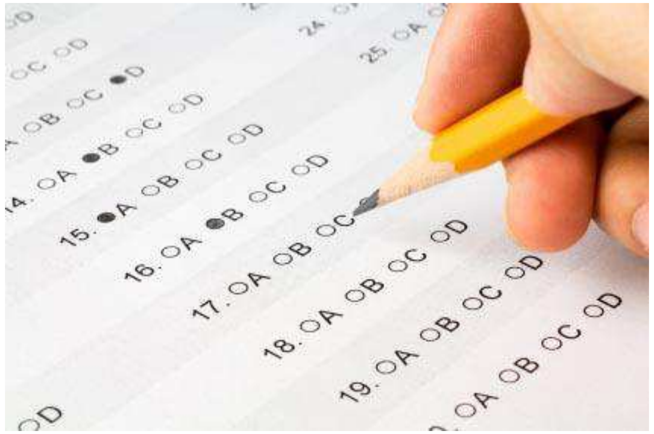

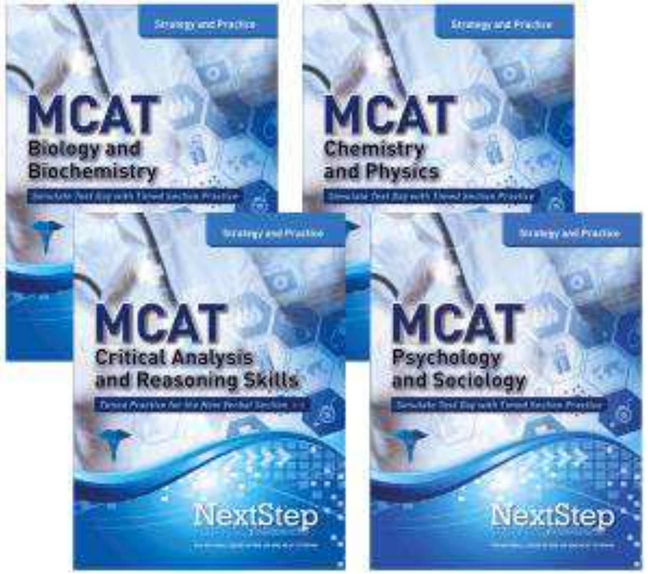

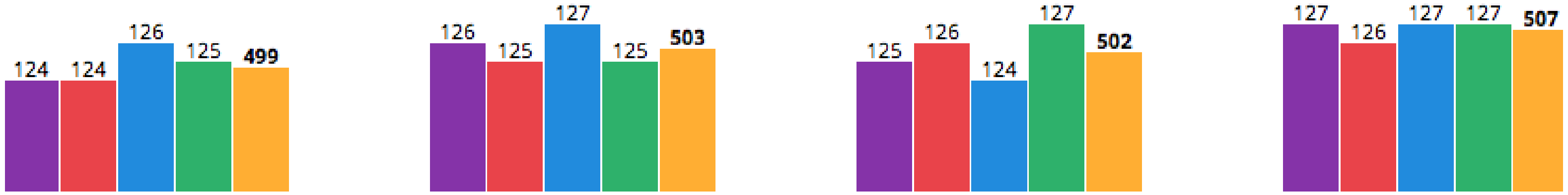

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Here's what our students have to say

Test prep isn't one-size-fits all and this is really **what sets Next Step apart**. When I studied for the MCAT the first time, I used Princeton Review and their strategies really did not work for me at all - they weren't personalized for my needs and actually hindered my progress while studying. Working with my tutor was completely different. From the beginning, **he really zeroed in on my specific weaknesses and over the course of my studying, he helped me develop the best strategies for me**. The skills I worked on with my tutor not only helped me get my dream score, but they actually helped me in my classes outside of the test as well. - Kyrra Sept 12,2017

When I initially took the MCAT, I got a 495. I was destroyed and thought all was lost. To prepare I had taken a once a week Kaplan course which gave me false confidence and an empty bank account. After **tutoring with NextStep I took the MCAT again with much more confidence and a better idea of what to expect** and got a 510. Two points higher than my goal score of a 508! My tutor was honest with me about what was realistic, yet encouraging. He showed me areas I needed to buckle down and improve on and helped me learn strategies to use my knowledge to its full potential. **I am so thankful for NextStep tutoring. They helped me conquer a test I had always feared. I recommend their services to anyone who is preparing for the MCAT.** I am now interviewing at various medical schools and get to go in confident about my score! Thank you Nextstep! - Talitha Sept 8, 2017

Next step is by far one of the strongest MCAT prep guides I have used. It is far more in tune with the difficult problems and passages that were on the 2017 MCAT , I especially love their focus on math and physics which was mostly ignored by Kaplan. Vlad - July 8, 2017

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