Chemistry review: Acids and Bases

Today's Info Session

- Introduction
- Discussion of titrations
- Equilibria
- Titrations
- How Can Next Step Help?
- Questions?

MCAT
Medical College Admission Test

Introduction

Hi, I'm Phil!

- MCAT Content writer
- Tutored and taught for 9+ years
- Attended University of Nebraska Medical Center as an MD/PhD student.

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- Began in 2009 as a tutoring company
- Focus on graduate admissions tests only
- Team of educational experts
- First company to have materials built from ground up for 2015 MCAT format
- Now the first company to have new 2018 MCAT Interface

✓ We never stop improving our materials!

Equilibria

Keq

$N_2 (g) + H_2(g) \leftrightarrow NH_3(g)$

$K_{eq} = [NH_3]^2 / [N_2][H_2]^3$

$HCl(aq) + H_2O (l) \leftrightarrow H_3O^+ + Cl^- (aq)$

$K_{eq} = [H_3O][Cl^-] / [HCl]$

Types of Keq: Ka, Kb, Ksp, Kd, Ka, Kw, Kr, Kf…

pH = pKa + log (Cb/A)

$HCl(aq) \leftrightarrow H^+ + Cl^- (aq)$

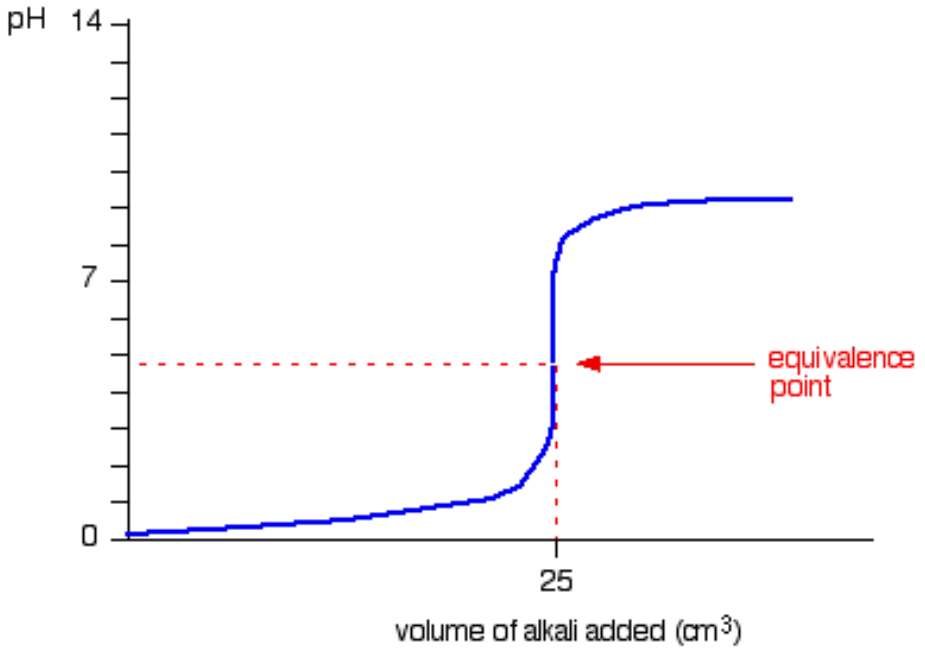
Titrations

Used to determine the concentration of an acid or base!

At equivalence point, we have one acid molecule for every base molecule

Ma Va = Mb Vb

If I started with 5 mL of an HCl solution and titrated with 1M of a Base as shown, what was my acid concentration?



Was it a strong or weak base?

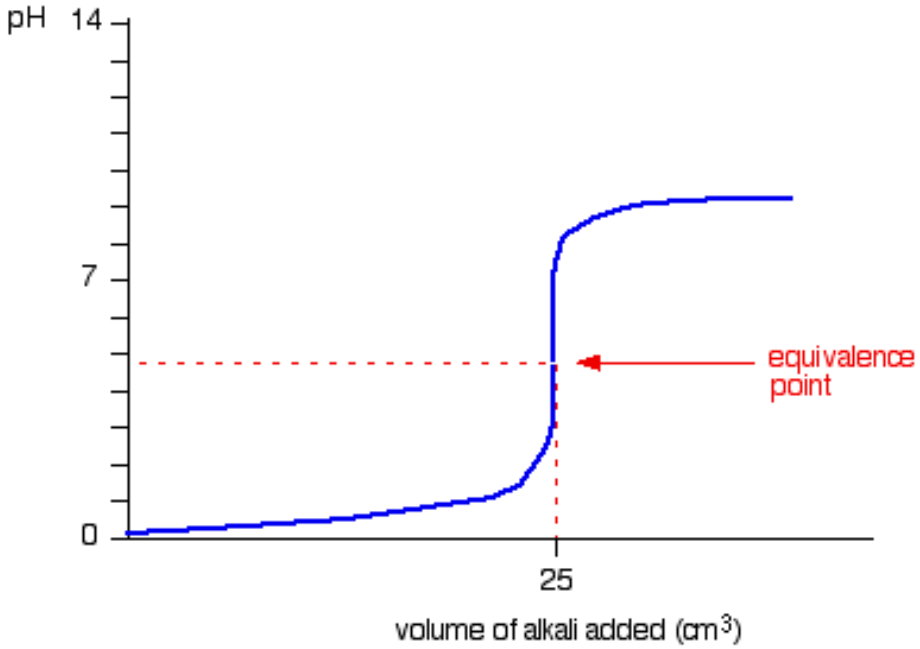
Titrations

Where on the graph will I find the most HCl?

HCl ← → H+ + Cl-

What happens at the ½ eq pt?

pH = pKa + log (Conjugate base/Acid)



Titrations

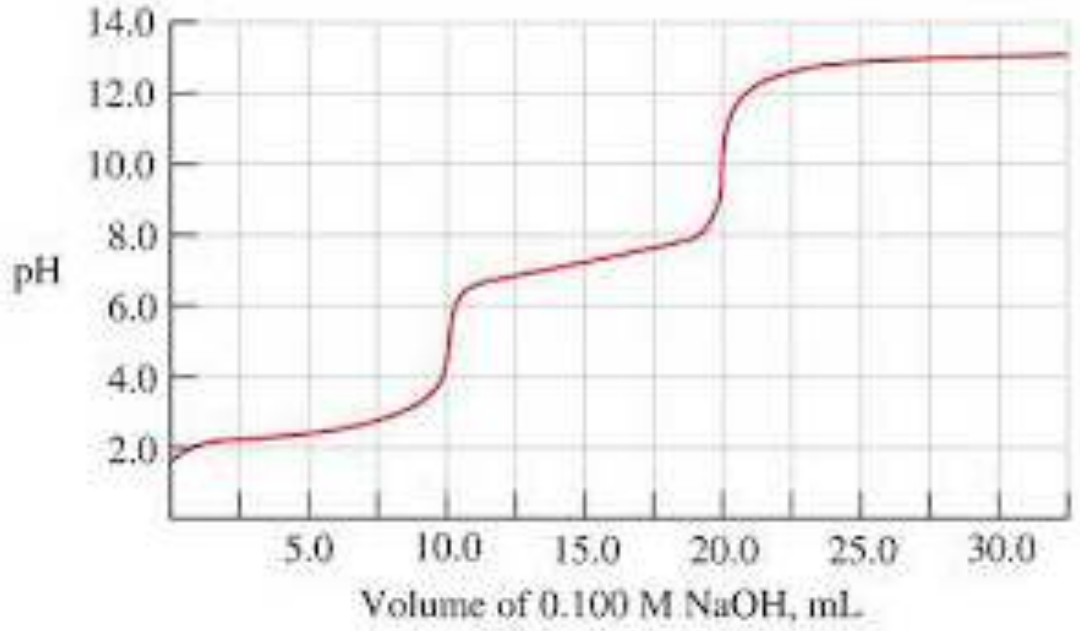
What can you tell me about my acid?

If I started with 5 mL of my acid, what is it's concentration?

Where on this graph will I find the most HSO4- ?

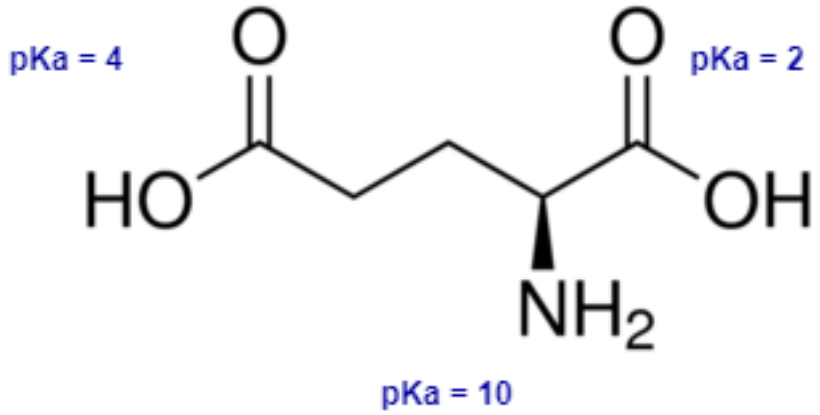
What are the pKas?

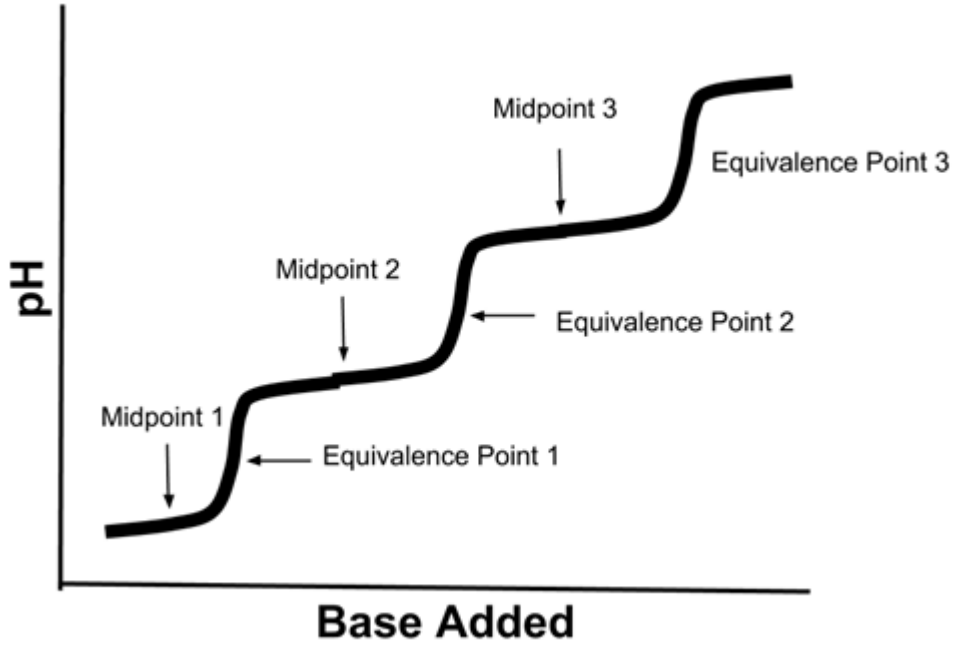
$H_2SO_4 \leftrightarrow HSO_4^- + H^+ \leftrightarrow SO_4^{2-} + 2H^+$



Titrations

What is the pH where this molecule has 0 charge overall?





Titrations

What is the pI for the following polypeptide?

DEVARH

pKa and pI values of amino acids

Amino acid	3-letter code	1-letter code	pKa C_α-COOH	pKa C_α-NH_3^+	pKa side chain	Isoelectric point (pI)
Alanine	Ala	A	2.34	9.69	-	6.02
Arginine	Arg	R	2.17	9.04	12.48	10.76
Asparagine	Asn	N	2.02	8.80	-	5.41
Aspartic acid	Asp	D	2.09	9.82	3.86	2.98
Cysteine	Cys	C	1.71	10.78	8.33	5.02
Glutamic acid	Glu	E	2.19	9.67	4.25	3.22
Glutamine	Gln	Q	2.17	9.13	-	5.65
Glycine	Gly	G	2.34	9.60	-	5.97
Histidine	His	H	1.82	9.17	6.00	7.59
Isoleucine	Ile	I	2.36	9.60	-	5.98
Leucine	Leu	L	2.36	9.60	-	5.98
Lysine	Lys	K	2.18	8.95	10.79	9.87
Methionine	Met	M	2.28	9.21	-	5.75
Phenylalanine	Phe	F	1.83	9.13	-	5.48
Proline	Pro	P	1.99	10.60	-	6.30
Serine	Ser	S	2.21	9.15	-	5.68
Threonine	Thr	T	2.09	9.10	-	5.60
Tryptophan	Trp	W	2.43	9.44	-	5.94
Tyrosine	Tyr	Y	2.20	9.11	10.07	5.66
Valine	Val	V	2.32	9.62	-	5.97

Practice Passage

Titration is used to determine the concentration of a particular compound in a solution. An acid-base titration starts with a known volume of the desired acid or base. An indicator that will change color near the equivalence point of the titration is added to the solution. Then, an acid or base, typically a strong acid or base, is added dropwise to the initial solution until the indicator changes color. Acid-base titration can be used to generate titration curves, an example of which is shown in Figure 1.

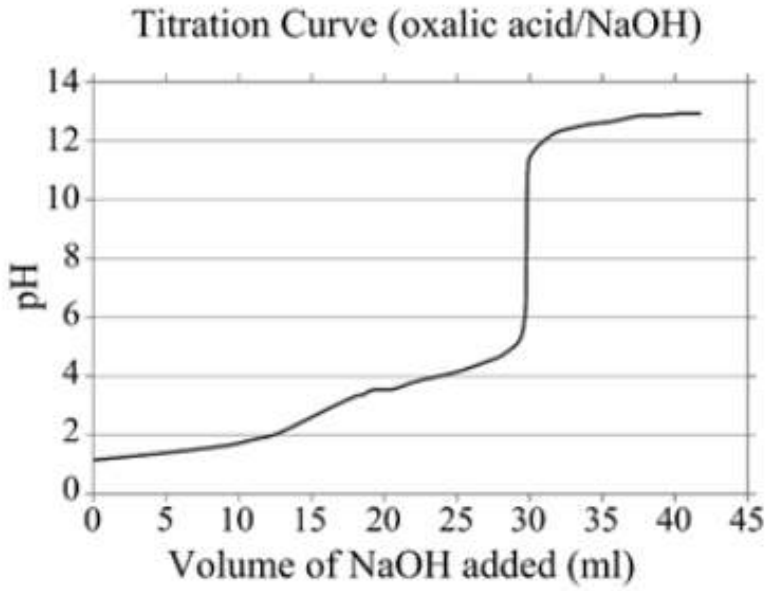


Figure 1 Titration of oxalic acid with NaOH

In order to keep track of titrations, specialized indicators are used. A drop of indicator solution is added to the titration at the beginning; the endpoint has been reached when the color changes. Selected pH indicators are listed in Table 1.

Indicator	Range of Color Change	Acidic Color	Basic Color
Methyl violet	0.0-1.6	Yellow	Violet
Bromophenol blue	3.0-4.6	Yellow	Blue
Methyl red	4.4-6.3	Red	Yellow
Bromothymol blue	6.0-7.6	Yellow	Blue
Naphtholphthalein	7.3-8.7	Red	Green
Phenolphthalein	8.3-10.0	Colorless	Pink

Table 1 Color Change and pH Range for Common Indicators

Isothermal Titration Calorimetry (ITC) uses the principles of calorimetry to determine binding parameters of a biomolecular binding reaction. The experimental setup of ITC is shown in Figure 2. Initially, water is added to the reference cell and a solution containing the protein or biomolecule of interest is added to the sample cell. The heat source heats each solution to the desired experimental temperature. The reference cell is held at a constant temperature throughout the experiment. Then, the ligand is added to the sample cell in small aliquots of known volume and concentration.

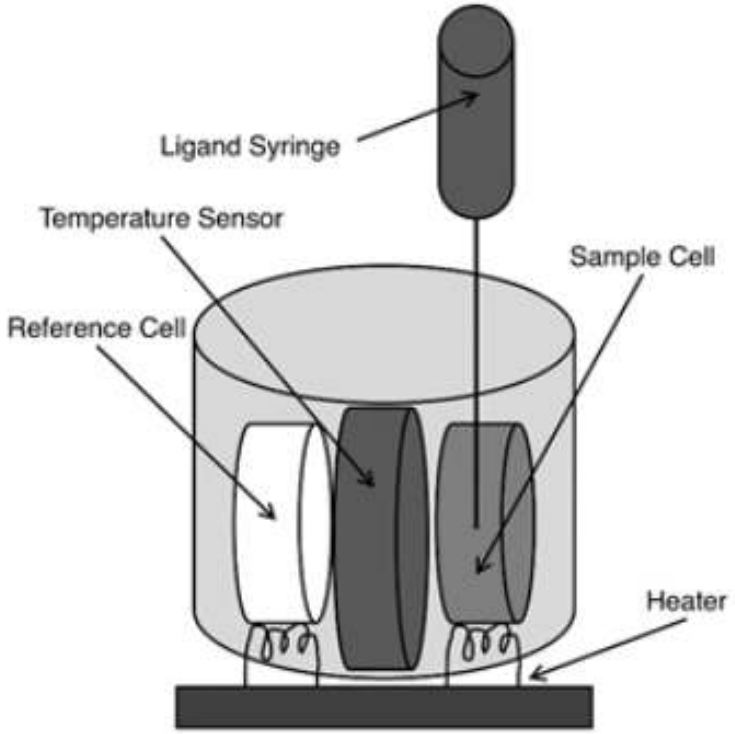
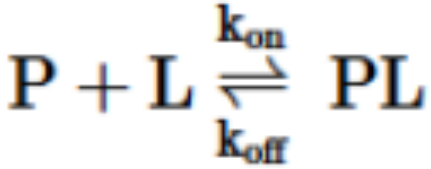


Figure 2 Isothermal Titration Calorimetry device

As the ligand is added to the sample solution, it binds to the protein or biomolecule in the solution. When the binding reaction occurs, heat is transferred between the reaction and the surrounding solution. The sensor detects the change in temperature between the sample cell and the reference cell and signals to the heater to adjust the heat transfer accordingly to return the sample cell to the desired experimental temperature. The heat transfer is measured throughout the reaction, and these measurements are used to determine the thermodynamic parameters and binding parameters for the reaction.

Questions

A scientist uses ITC to determine the thermodynamic parameters of the exergonic reaction between a protein (P) and its ligand (L).



Measurements reveal that as the ligand is added to the sample cell, the rate of heat transfer from the heater to the sample cell is increased. Which of the following must be true of the forward reaction?

I. $\Delta H > 0$
II. $\Delta S > 0$
III. $\Delta G > 0$

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

Questions

A researcher is titrating an oxalic acid solution with NaOH as shown in Figure 1. Which indicator is the most appropriate for the titration shown in Figure 1?

A. Bromophenol blue
B. Methyl Red
C. Bromothymol blue
D. Naphtholphthalein

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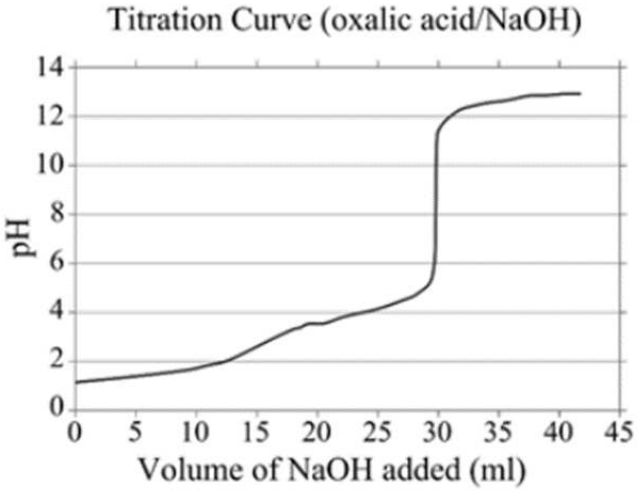


Questions

The thermodynamic parameters of a binding reaction were determined using isothermal titration calorimetry with the temperature held at 37ºC. What is the ΔG for the reaction at 37ºC?

A. -1570 kJ/mol
B. -230 kJ/mol
C. 230 kJ/mol
D. 1570 kJ/mol

ΔH	-220 kJ/mol
ΔS	36.6 J/mol•K
K_D	3.4×10^{-9} M
Protein Concentration	0.05 μM
pH	7.4

Questions

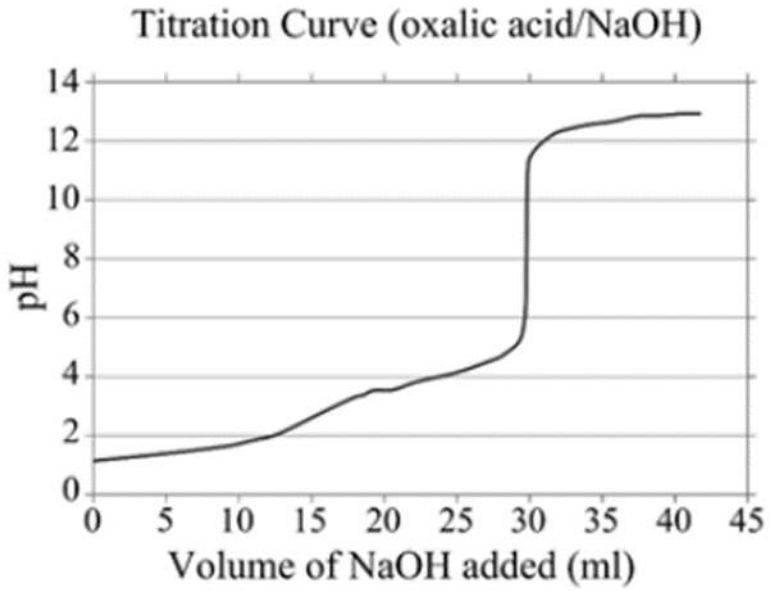
Based on the titration shown in Figure 1, what is the pK_a of oxalic acid?

A. 1.5

B. 3.5

C. 8.0

D. 13.0



Questions

Nitrous acid and its conjugate base are combined in a 1 to 5 ratio to form a 100 mL buffer solution. If the K_a of nitrous acid is approximately 4.0×10^{-4}, what is the pH of the buffer solution?

A. 2.7

B. 3.4

C. 4.1

D. 6.5

$pH = pKa + \log (Cb/A)$

$pKa = - \log (Ka)$

Questions

For which of the following titrations would methyl red be an accurate indicator?

A. Strong acid/weak base
B. Strong base/weak acid
C. Strong acid/strong base
D. Weak acid/weak base

Indicator	Range of Color Change	Acidic Color	Basic Color
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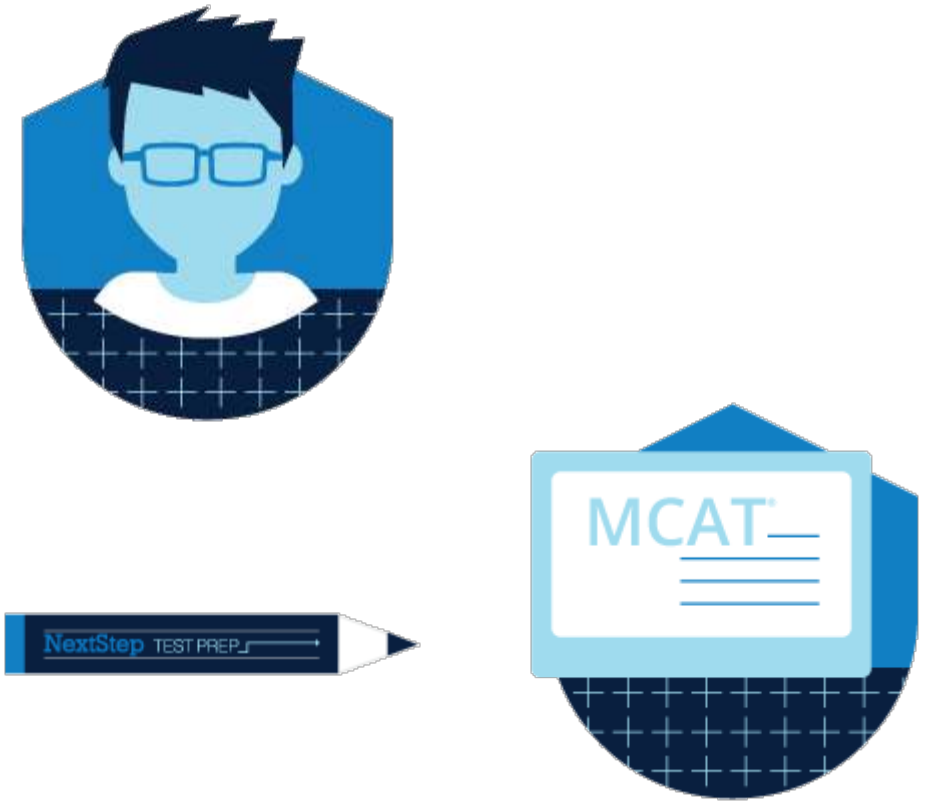

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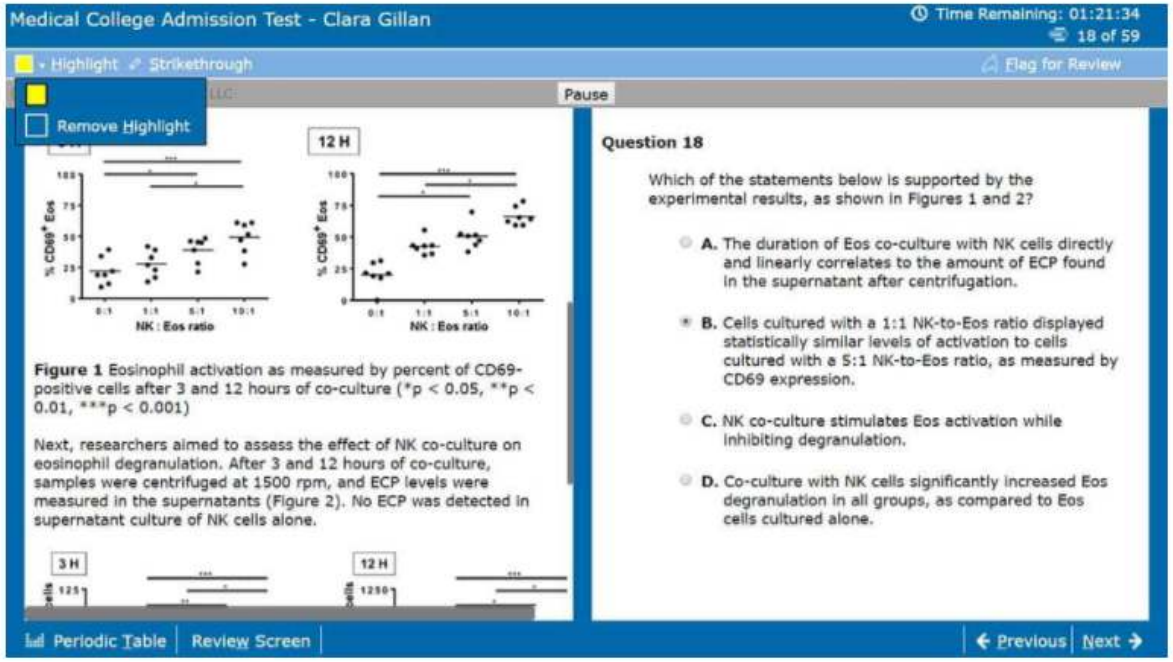

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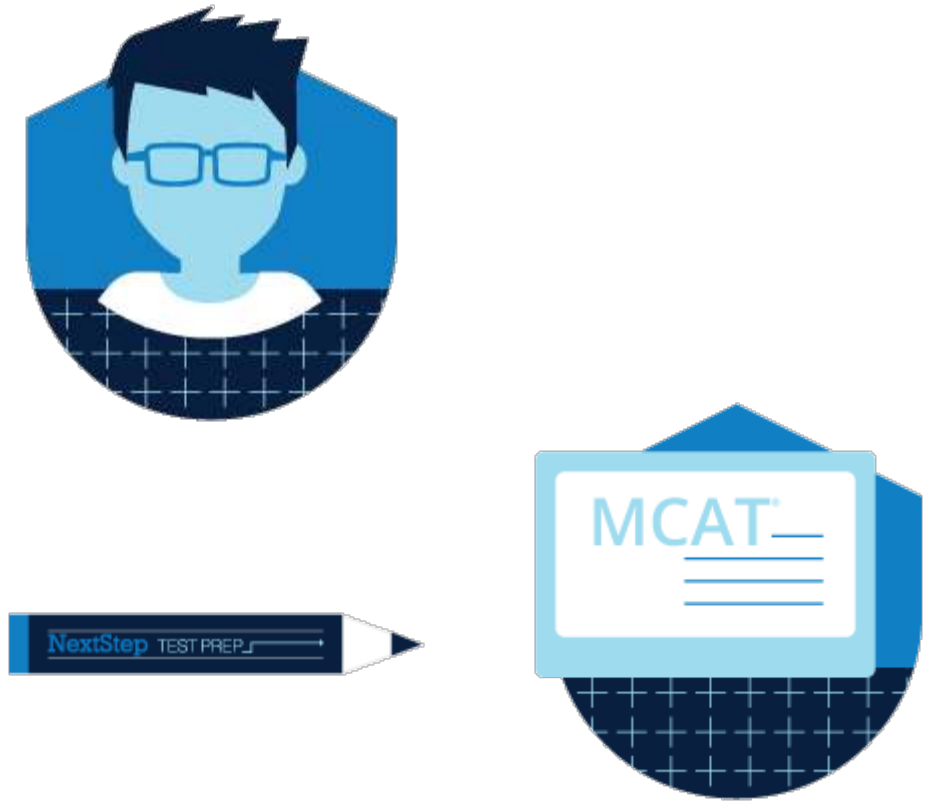

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