5.111 Principles of Chemical Science

Fall 2008

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Selected biology-related questions from problem sets for lectures 21-26

Acid-base problems

A.
A pharmaceutical molecule with antifungal properties is only active when deprotonated and negatively charged (A^-). The protonated state (HA) is inactive. If the pK_a of this drug is 10.0, **(a)** calculate the ratio of protonated to deprotonated compound at physiological pH (7.4). (**b**) Is this drug likely to be a useful pharmaceutical agent?

B.
Absorption of aspirin (acetylsalicylic acid, $C_9H_8O_4$,) into the bloodstream occurs only when the molecule is in its conjugate base form.

(a) If a patient takes two tablets of aspirin (325 mg each), how many grams of aspirin are available for immediate absorption in the stomach? The pH of the stomach is 1.6, and the pK_a of aspirin is 3.5.

(b) Would you expect more or less aspirin to be absorbed in the small intestine (pH ≈ 7.5) compared to the stomach? Briefly explain your answer (no calculation is required).

C. (Modified from problem 11.18 in Atkins 3rd ed)
Phosphate buffers are very useful in biochemical experiments. Your research supervisor asks you to make up a phosphate buffer to carry out kinetic assays on an enzyme:

(a) Determine the ratio of molarities of PO_4^{3-} and HPO_4^{2-} ions required to prepare a phosphate buffer with a pH of 12.0?

(b) What mass of K_3PO_4 must be added to 1.00 L of 0.100 M K_2HPO_4(aq) to prepare a buffer solution with a pH of 12.0?

Oxidation-reduction problems

D.
Hydrogen peroxide (H_2O_2) is a harmful and reactive byproduct of metabolism. To prevent H_2O_2 from causing extensive oxidative damage to cells, the enzyme catalase catalyzes the conversion of H_2O_2 to much less reactive molecules, oxygen and water.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

Use oxidation numbers to identify which molecules are reduced and/or oxidized in this reaction.

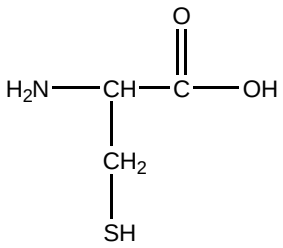
E.
Oxidative damage of DNA leads to mutation, which can in turn lead to cancer or genetic defects. The redox potentials of the four nucleotides of DNA are listed below. Which

nucleotide (A, G, T, C) is the most likely to undergo oxidation? Explain your answer for full credit.

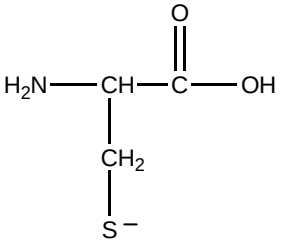
Nucleotide	ε (V)
G	**1.33**
A	**1.42**
C	**1.60**
T	**1.70**

F.
The enzyme known as laccase is a multicopper oxidase that is widely distributed in higher plants and fungi. The $Fe(CN)_6^{4-}$ complex was used to study the structure of the active site of this enzyme.
(a) Indicate the oxidation number of the central atom in this complex.
(b) Calculate the d-electron count
(c) What is the coordination geometry?

G.
Zinc can act as a Lewis acid, and coordinate amino acids like cysteine by their sulfhydryl (SH) groups. Normally, the sulfhydryl group of cysteine has a pK_a of ~8. However, the interaction with zinc can lower the pK_a of the sulfhydryl group by as much as 4 pH units. Using your knowledge of acid/base chemistry, estimate the approximate ratio of protonated to deprotonated cysteine at neutral pH for **(a)** free cysteine (pK_a of ~ 8) and **(b)** cysteine coordinated to zinc (pK_a of ~ 4). (Since this is an estimate, don't worry about sig figs).



protonated cysteine



deprotonated cysteine