

Module 2: Study Guide Questions

1. Given the reaction $A+B \rightarrow C+D$ and using $\Delta G^\circ = -RT \ln K_{eq}$: (Useful calculations: $\ln 1 = 0$, $\ln < 1 = \text{negative}$, $\ln > 1 = \text{positive}$.)

(A) if, at equilibrium, the products concentrations equaled 2M and the reactants concentrations equaled 1M, would ΔG° be positive or negative and would this reaction be favorable or unfavorable as written?

(B) if, at equilibrium, the products concentrations equaled 1M and the reactants concentrations equaled 2M, would ΔG° be positive or negative and would this reaction be favorable or unfavorable as written?

(C) What does ΔG° tell you about the reactants, A and B and the products, C and D?

(D) What else do you need to know to determine if this reaction is favorable in a cell?

2. Draw free energy change diagrams (G vs. Reaction plot) for the following: $\Delta G < 0$, $\Delta G > 0$, $\Delta G = 0$ for reaction $X \rightarrow Y$.

3. Describe an experiment to determine how and if cells obey the second law of thermodynamics. Include

(A) what the second law of thermodynamics states,

(B) a description of the experiment, and

(C) the results and how they indicate whether cells obey this law.

4. Consider the reaction equation for hydrolysis of ATP: $ATP + H_2O \rightleftharpoons ADP + P_i + H^+$. What determines whether this reaction is favorable in a cell? Your description should be in terms of

(A) $\Delta G_{\text{reaction}} = \Delta G^\circ + RT \ln K$

(B) intrinsic properties, and

(C) system properties.

5. ΔG° of a chemical reaction is dependent on the enthalpy and entropy of the products and the reactants.

(A) Describe the thermodynamic laws that pertain to enthalpy and entropy.

(B) Using the jumping bean analogy, describe how enthalpy and entropy determine if a reaction is favorable or unfavorable as written.

(C) Using the equation $\Delta G^\circ = \Delta H - T\Delta S$ and bar graphs (described in class) to describe their role in determining if a reaction is spontaneous as written.

6. Given that $\Delta G_{\text{reaction}} = \Delta G^\circ + RT \ln K$ and using the jumping bean analogy,

(A) describe the role of K_{eq} and K in determining if a reaction is spontaneous as written.

(B) What is the relative ($<$, $>$, $= 1$) ratio of products to reactants at equilibrium and under cellular conditions for ATP hydrolysis?

(C) Using the table in the slides for lecture 5, what would be the ΔG° and $\Delta G_{\text{reaction}}$ for reactions with $[B]/[A]$ ratios at equilibrium and starting conditions, respectively, of 10^3 , 10^1 , 1, 10^{-1} and 10^{-3} ?

7. Many reactions that a cell must have occur to live and grow are thermodynamically unfavorable.

(A) What is meant by thermodynamically unfavorable?

(B) How do cells “drive” these reactions to occur?

(C) How is glutamine synthesis from glutamate and NH_4^+ ($\Delta G^\circ = 4 \text{ kcal/mole}$) driven in cells thermodynamically and mechanistically?

8. Instant cold packs get cold when the contents, usually solid urea and liquid water, are mixed, producing an aqueous solution of urea. Although this process is clearly spontaneous, the products are colder than the reactants. Explain how this is possible in terms of the difference between ΔG and ΔH .

9. Rank the following bonds or interactions in order of strength: hydrogen bond, covalent bond, ionic bond, and van der Waals interaction. What typical strengths (ΔG°) of these bonds/interactions in kcal/mole? How does the environment (e.g. water vs. vacuum) affect each type of bond/interaction?

10. True or false: All single, non-covalent bonds or interactions are too weak to withstand the thermal motions ($\sim 1 \text{ kcal/mole}$) that tend to pull interacting molecules apart.

11. Which type of non-covalent interaction is favored by (in fact, dependent on) an aqueous environment and strengthened by the presence of added ions?

12. Briefly describe that key attributes of the four types of non-covalent bonds/interactions/forces.

13. Explain the fact that ethanol ($\text{CH}_3\text{CH}_2\text{OH}$) is more soluble in water than is ethane (CH_3CH_3).

14. For each of the pairs below, which is the conjugate base.

1a. RCOOH 1b. RCOO^-

2a. RNH_2 2b. RNH_3^+

3a. H_2PO_4^- 3b. H_3PO_4

4a. H_2CO_3 4b. HCO_3^-

15. Phosphoric acid (H_3PO_4) has three dissociable protons, with the pK_a 's shown below. Which form of phosphoric acid predominates in a solution at pH 4? Explain your answer.

Acid	pK_a
H_3PO_4	2.14
H_2PO_4^-	6.86
HPO_4^{2-}	12.4

16. Define pK_a for a weak acid in the following two ways: (1) in relation to its acid dissociation constant, K_a , and (2) by reference to a titration curve for the weak acid.

17. Describe the key aspects of the shared common structure between the 20 common amino acids.

18. What are the three main classifications of amino acids as described in class? Describe any sub-classifications of these three main classifications. What portion of each amino acid determines how it is classified? Provide an example for each class of amino acid.

19. Why are most amino acids soluble in water? Are amino acids weak or strong acids and bases? At what pH does glycine have a net charge of -1? What is the net charge of glycine at its pI ? Is the pK_a of the amino and carboxyl groups of all amino acids the same?

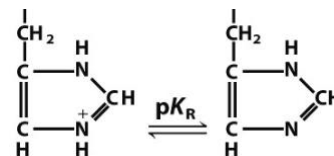
20. Draw the structures of the amino acids phenylalanine and aspartate in the ionization state you would expect at pH 7.0. Why is aspartate very soluble in water, whereas phenylalanine is much less soluble?

21. The amino acid histidine has three ionizable groups, with pK_a values of 1.8, 6.0, and 9.2.

a. Which pK_a corresponds to the histidine side chain?

b. Which functional groups are the other pK_a s for?

c. In a solution at pH 5.4, will more than half, less than half, or exactly half of the histidine side chains carry a positive charge?



d. What will be the overall net charge of the histidine molecules after addition of 2 OH^- equivalents?

e. Which of the three diagrams represents the titration curve on a pH vs. NaOH equivalents plot?

f. Which of the four diagrams represents the protonation state of the histidine functional groups at this net charge?