1. The free energy change of a chemical reaction varies with the concentration of reactants and products. The relationship is given by the reaction isotherm:

$$\Delta G = \Delta G^\circ + RT \ln Q'$$

(a) What is the significance of the prime (') in $\Delta G^\circ$ and $Q'$?

(b) What is the relationship between $Q'$ and $K'_{eq}$ for a spontaneous reaction?

2. Reactions near equilibrium have $\Delta G$ values low, near zero, while reactions that are irreversible or far from equilibrium have large negative $\Delta G$ values. In the list of enzymes of glycolysis and the TCA cycle listed below, but check by the enzymes that operate near equilibrium.

- hexose phosphate isomerase
- triose phosphate dehydrogenase
- succinate dehydrogenase
- phosphoglycerate mutase
- 3-phosphoglycerate kinase
- citrate synthase
- isocitrate dehydrogenase
- malate dehydrogenase
- alpha keto glutarate dehydrogenase
- phosphofructokinase

3. Starting with $[1-^{14}C]$-glucose, predict which carbon(s) would be labeled in the following intermediates after glycolysis and during the first turn of the TCA cycle. (Draw the structure of the intermediate and circle the labeled carbon atom).

(a) pyruvate  (b) isocitrate  (c) alpha-keto glutarate  (c) malate
4. Below are the partial structures of seven coenzymes you have studied. Below each structure give the name of the coenzyme and draw an alternative form of the coenzyme to which it is converted during the course of a reaction.

A. B. C. 

D. E. F. G.

5. Your textbook gives the reaction catalyzed by succinate dehydrogenase as:

\[
\text{succinate} + \text{FAD} \rightarrow \text{fumarate} + \text{FADH}_2
\]

Your instructor prefers to write the reaction as:

\[
\text{succinate} + \text{CoQ} \rightarrow \text{fumarate} + \text{CoQH}_2
\]

Explain why.
6. In the presence of cyanide and excess cytochrome c, mitochondria can carry out the following reaction (where the NADH is generated from oxidation of substrates via the TCA cycle):

\[ \text{NADH} + 2 \text{cyt c(ox)} \rightarrow \text{NAD} + 2 \text{cyt c(red)} \]

(a) Calculate \( \Delta G^\circ \) for this reaction.

\( E'_o \) for NAD/NADH is \(-0.32\) volts and for cyt c(ox)/cyt c(red) is \(+0.25\) volts; \( F = 96.5 \text{ kJ mol}^{-1} \text{ volt}^{-1} \)

(b) Identify all the intermediate electron carriers involved in this reaction, indicating which are organized in multiprotein complexes.

(c) If these mitochondria are tightly coupled to ATP synthesis, what molar ratio of ATP made to NADH oxidized would you expect? Explain your answer.

(d) Why is it necessary to add cyanide to observe this reaction?

7. **Oligomycin** would block the reduction of cytochrome c described in question 2 if the mitochondria are tightly coupled to ATP synthesis, but **dinitrophenol** would relieve this inhibition allowing cytochrome c reduction to resume. Explain how these two inhibitors would be interacting with the system to show these effects.
(18) 8. Following is an alphabetical list of the intermediate electron carriers found in the
mitochondrial electron transport chain. Identify the carriers that fit each description on the
right by placing the letter of the carrier(s) in the blank next to the description. A carrier
may be used more than once.

<table>
<thead>
<tr>
<th>Electron Carrier</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Coenzyme Q</td>
<td>A component of Complex I __________________________</td>
</tr>
<tr>
<td>(b) CuA</td>
<td>A component of Complex II __________________________</td>
</tr>
<tr>
<td>(c) CuB</td>
<td>A component of Complex III __________________________</td>
</tr>
<tr>
<td>(d) cytochrome a</td>
<td>A component of Complex IV __________________________</td>
</tr>
<tr>
<td>(e) cytochrome a₃</td>
<td>Carries electrons from Complex II to Complex III ______</td>
</tr>
<tr>
<td>(f) cytochrome b₇H</td>
<td>Carries electrons from Complex III to Complex IV ______</td>
</tr>
<tr>
<td>(g) cytochrome b₇L</td>
<td>Forms a binuclear center for oxygen reduction __________</td>
</tr>
<tr>
<td>(h) cytochrome c</td>
<td>Accepts electrons directly from succinate ____________</td>
</tr>
<tr>
<td>(i) cytochrome c₁</td>
<td>Accepts electrons directly from NADH _________________</td>
</tr>
<tr>
<td>(j) FAD</td>
<td></td>
</tr>
<tr>
<td>(k) Fe/S center</td>
<td></td>
</tr>
<tr>
<td>(l) FMN</td>
<td></td>
</tr>
</tbody>
</table>

(15) 9. A number of components are involved in the light reaction of plant photosynthesis. Match
a component in the list at the right with each statement below by placing the appropriate
letter in the blank. Only one component may be used per blank. (P700 is photosystem I, P680 is photosystem II).

_____ reduced directly by P680⁺  a. Z, a tyrosine residue
_____ reduced directly by P700⁺  b. phycocyanin
_____ oxidized directly by P680⁺  c. plastocyanin
_____ oxidized directly by P700⁺  d. Ao, a chlorophyll molecule
_____ an accessory pigment       e. pheophytin
_____ chlorophyll a without Mg²⁺ f. cytochrome a₃
_____ reduced by cytochrome b/f complex g. ferredoxin
_____ removes electrons from the Mn cluster
_____ a Cu containing protein
_____ an Fe/S protein