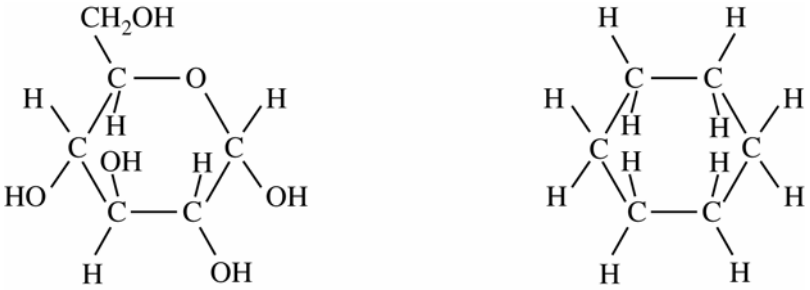
Question 6

6. Answer each of the following in terms of principles of molecular behavior and chemical concepts.

(a) The structures for glucose, $C_6H_{12}O_6$, and cyclohexane, C_6H_{12}, are shown below.



Identify the type(s) of intermolecular attractive forces in

(i) pure glucose

Hydrogen bonding OR dipole-dipole interactions OR van der Waals interactions (London dispersion forces may also be mentioned.)	One point is earned for a correct answer.

(ii) pure cyclohexane

London dispersion forces	One point is earned for London dispersion forces.

(b) Glucose is soluble in water but cyclohexane is not soluble in water. Explain.

The hydroxyl groups in glucose molecules can form strong hydrogen bonds with the solvent (water) molecules, so glucose is soluble in water. In contrast, cyclohexane is not capable of forming strong intermolecular attractions with water (no hydrogen bonding), so the water-cyclohexane interactions are not as energetically favorable as the interactions that already exist among polar water molecules. **OR** • Glucose is polar and cyclohexane is nonpolar. • Polar solutes (such as glucose) are generally soluble in polar solvents such as water. • Nonpolar solutes (such as cyclohexane) are not soluble in the polar solvent.	One point is earned for explaining the solubility of glucose in terms of hydrogen bonding or dipole-dipole interactions with water. One point is earned for explaining the difference in the polarity of cyclohexane and water. **OR** One point is earned for any one of the three concepts; two points are earned for any two of the three concepts.

Question 6 (continued)

(c) Consider the two processes represented below.

Process 1: $H_2O(l) \rightarrow H_2O(g)$ $\Delta H^\circ = +44.0 \text{ kJ mol}^{-1}$

Process 2: $H_2O(l) \rightarrow H_2(g) + \frac{1}{2} O_2(g)$ $\Delta H^\circ = +286 \text{ kJ mol}^{-1}$

(i) For each of the two processes, identify the type(s) of intermolecular or intramolecular attractive forces that must be overcome for the process to occur.

In process 1, hydrogen bonds (or dipole-dipole interactions) in liquid water are overcome to produce distinct water molecules in the vapor phase.	One point is earned for identifying the type of intermolecular force involved in process 1.
In process 2, covalent bonds (or sigma bonds, or electron-pair bonds) within water molecules must be broken to allow the atoms to recombine into molecular hydrogen and oxygen.	One point is earned for identifying the type of intramolecular bonding involved in process 2.

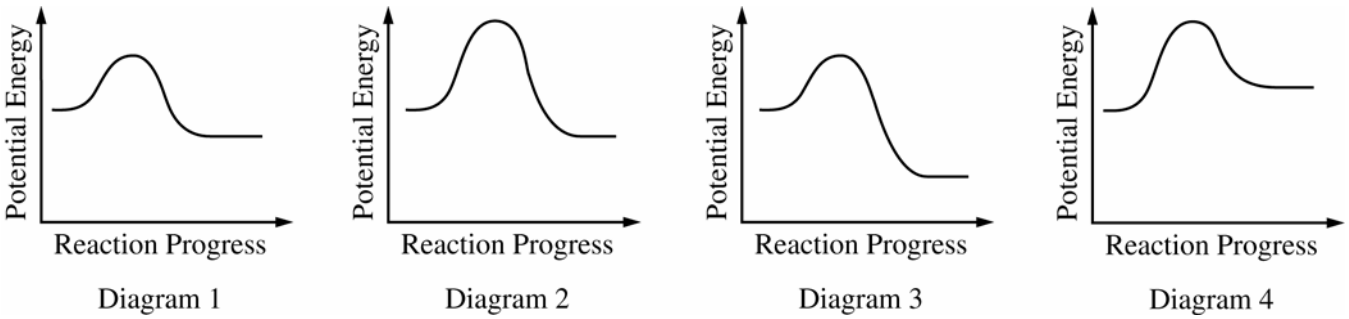
(ii) Indicate whether you agree or disagree with the statement in the box below. Support your answer with a short explanation.

> When water boils, H_2O molecules break apart to form hydrogen molecules and oxygen molecules.

I disagree with the statement. Boiling is simply Process 1, in which only intermolecular forces are broken and the water molecules stay intact. No intramolecular or covalent bonds break in this process.	One point is earned for disagreeing with the statement and providing a correct explanation.

Question 6 (continued)

(d) Consider the four reaction-energy profile diagrams shown below.



(i) Identify the two diagrams that could represent a catalyzed and an uncatalyzed reaction pathway for the same reaction. Indicate which of the two diagrams represents the catalyzed reaction pathway for the reaction.

Diagram 1 represents a catalyzed pathway and diagram 2 represents an uncatalyzed pathway for the same reaction.	One point is earned for identifying the correct graphs and indicating which represents which pathway.

(ii) Indicate whether you agree or disagree with the statement in the box below. Support your answer with a short explanation.

Adding a catalyst to a reaction mixture adds energy that causes the reaction to proceed more quickly.

I disagree with the statement. A catalyst does not add energy, but provides an alternate reaction pathway with a lower activation energy.	One point is earned for disagreeing with the statement and providing an explanation.

(d) Consider the four reaction-energy profile diagrams shown below.

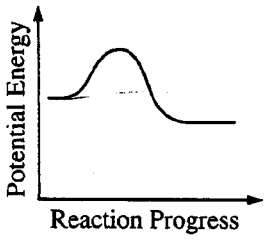


Diagram 1

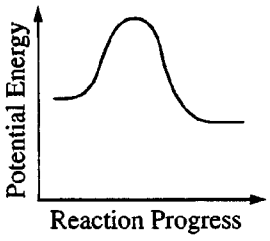


Diagram 2

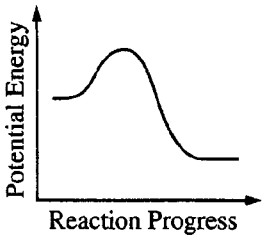


Diagram 3

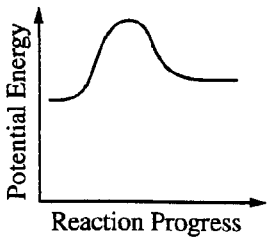


Diagram 4

(i) Identify the two diagrams that could represent a catalyzed and an uncatalyzed reaction pathway for the same reaction. Indicate which of the two diagrams represents the catalyzed reaction pathway for the reaction.

(ii) Indicate whether you agree or disagree with the statement in the box below. Support your answer with a short explanation.

Adding a catalyst to a reaction mixture adds energy that causes the reaction to proceed more quickly.

a) i. glucose has hydrogen bonding and london dispersion forces. It also should have slight dipole forces.

ii. cyclohexane only has london dispersion forces.

b) Because glucose is slightly polar and has hydrogen bonding it is soluble in water due to water's hydrogen bonding and polarity. Cyclohexane is not polar so it is not attracted to the polar water molecules.

c) i. In process one the intermolecular forces of the hydrogen bonding and dipole-dipole must be broken along with the london dispersion forces. In process two the hydrogen bonding, dipole-dipole and london dispersion forces must be broken in addition to the polar bonds between H-O.

GO ON TO THE NEXT PAGE.

ADDITIONAL PAGE FOR ANSWERING QUESTION 6.

C) ii. I don't agree with the statement. When water boils the intermolecular forces are broken not the intra molecular bonds. Water just changes phase.

D) i. Diagram two could be the uncatalyzed reaction and diagram one could be the catalyzed reaction. Diagram one has a lower activation energy than diagram two which means a catalyst could have been used. The potential for the reactants and products are the same.

ii. I don't agree with the statement. The addition of a catalyst doesn't add energy, it decreases the amount of energy needed for the reaction to occur.

(d) Consider the four reaction-energy profile diagrams shown below.

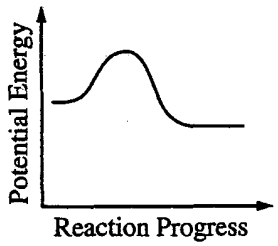


Diagram 1

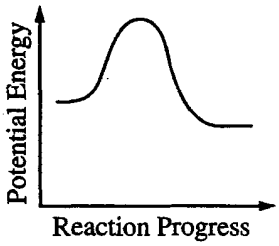


Diagram 2

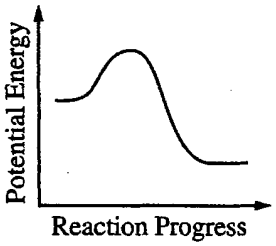


Diagram 3

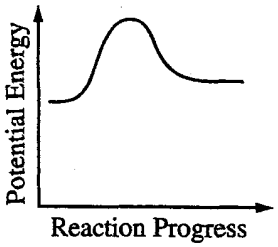


Diagram 4

(i) Identify the two diagrams that could represent a catalyzed and an uncatalyzed reaction pathway for the same reaction. Indicate which of the two diagrams represents the catalyzed reaction pathway for the reaction.

(ii) Indicate whether you agree or disagree with the statement in the box below. Support your answer with a short explanation.

Adding a catalyst to a reaction mixture adds energy that causes the reaction to proceed more quickly.

6. a) i) London dispersion forces, covalent bonds

ii) Covalent & london dispersion forces

b) Glucose is a polar molecule which allows it to be soluble in polar water. Cyclohexane is a symetric, non-polar molecule and therefore is not solvate in water.

c) (i) In order for water to change from a liquid to a gas, it would have to overcome the london dispersion forces.

(ii) I disagree with the statement because when water boils, the water escapes in the form of water vapor or H_2O molecules, not as hydrogen and oxygen gas.

ADDITIONAL PAGE FOR ANSWERING QUESTION 6.

d) (i) diagram 1 & 2: the activation energy between these two diagrams increases. The first diagram has a smaller hump, or activation energy and therefore is catalyzed. The second graph has a higher activation energy and therefore is uncatalyzed. Both graphs have the same ΔH and therefore represent the two catalyzed and uncatalyzed reaction pathways.

(ii) I disagree with the statement because adding a catalyst decreases the activation energy. Decreasing the activation energy causes the reaction to proceed at a faster rate.

(d) Consider the four reaction-energy profile diagrams shown below.

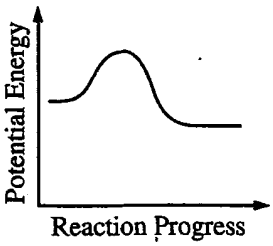


Diagram 1

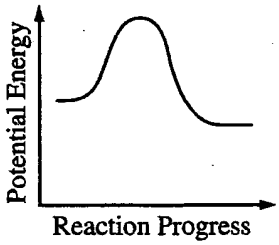


Diagram 2

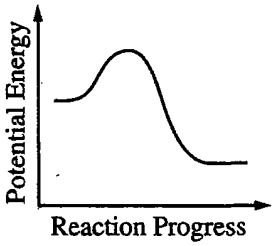


Diagram 3

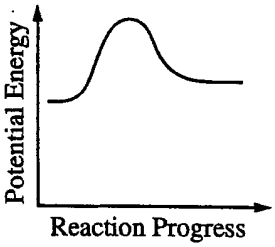


Diagram 4

(i) Identify the two diagrams that could represent a catalyzed and an uncatalyzed reaction pathway for the same reaction. Indicate which of the two diagrams represents the catalyzed reaction pathway for the reaction.

(ii) Indicate whether you agree or disagree with the statement in the box below. Support your answer with a short explanation.

Adding a catalyst to a reaction mixture adds energy that causes the reaction to proceed more quickly.

6 (a) (i) covalent

(ii) covalent

(b) Cyclohexane does not form ions in water. Cyclohexane is nonpolar. glucose is polar.

(c)(i) Process 1: hydrogen bonds broken

2: molecular forces overcome

(ii) Disagree. When water boils, it is going through a phase change from liquid to gas. Molecules are moving farther apart because hydrogen bonds between mlcs are being broken

(d) on next page →

ADDITIONAL PAGE FOR ANSWERING QUESTION 6.

d. (i) Diagram 1 and 2
Diagram is catalyzed.

(ii)
I agree. Adding a catalyst lowers the activation E. ∴ There is a better chance of the rxn obtaining enough E → rxn more likely to happen.
Catalyst provides an alternate pathway for the rxn that may be faster.

AP® CHEMISTRY
2006 SCORING COMMENTARY

Question 6

Overview

Two areas in the AP Chemistry curriculum were explored in this question: the role of inter *vs.* intramolecular forces (parts (a), (b) and (c)), and the effect of catalysts on chemical reactions (part (d)). In part (a) students were asked to identify the intermolecular forces between glucose molecules in pure glucose (a)(i) and between cyclohexane molecules in pure cyclohexane (a)(ii). Part (b) asked them to account for the solubility of glucose in water and the relative insolubility of cyclohexane in the same solvent. The types of intermolecular and intramolecular forces cleaved in two different reactions had to be identified in part (c). For part (d) the question skipped to the topic of kinetics, and students were asked to identify the reaction coordinate graphs appropriate for a catalyzed and uncatalyzed version of the same reaction and to explain the role of a catalyst in a reaction.

Sample: 6A
Score: 9

This response earned all 9 points: 1 point for part (a)(i), 1 point for part (a)(ii), 2 points for part (b), 2 points for part (c)(i), 1 point for part (c)(ii), 1 point for part (d)(i), and 1 point for part (d)(ii). The response is clear and succinct.

Sample: 6B
Score: 5

Even though London dispersion forces are mentioned in parts (a)(i) and (a)(ii), the points were not earned because the inclusion of covalent bonds indicates confusion between intermolecular and intramolecular forces. Both points were earned in part (b), but the points were not earned in part (c)(i) because the wrong forces are used to explain the phase change in Process 1, and Process 2 is not discussed. The point was earned in part (c)(ii), and both points were earned in part (d).

Sample: 6C
Score: 3

The points were not earned in parts (a)(i) and (a)(ii). In part (b) 1 out of 2 possible points was earned because the response states that cyclohexane is nonpolar and glucose is polar, but the student does not say anything about the polarity of water or the solubility of polar or nonpolar substances in water. In part (c)(i) 1 point was earned for stating that hydrogen bonds are broken in Process 1; the point for explaining Process 2 was not earned. The point was earned in part (c)(ii). The point was not earned in part (d)(i) because the response does not state which diagram represents the catalyzed reaction pathway. The point was not earned in part (d)(ii), even though the explanation is correct, because the student agrees with the statement.