Name (Last, First): _____ ID Number: _____

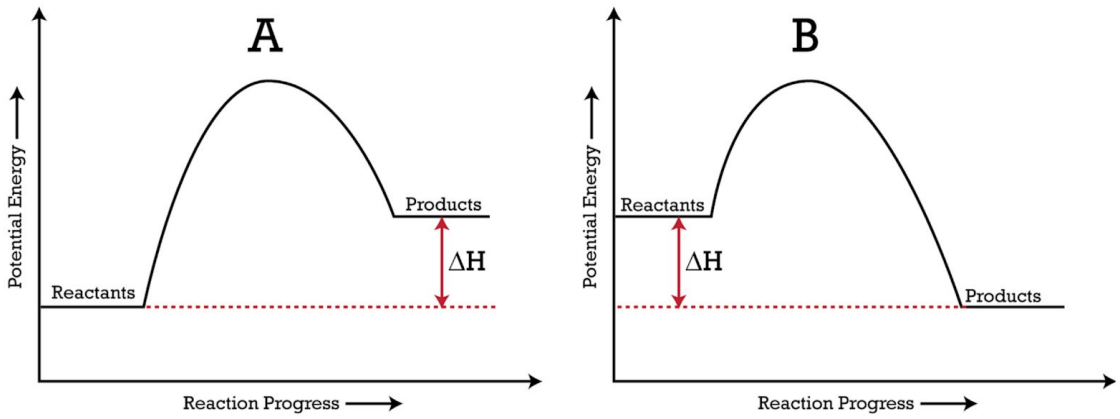
WUCT: Chemistry of Oceans Sample

1. Hydrothermal vents of deep oceans are home to organisms that do not rely on photosynthesis for food and energy production. Instead, these organisms rely on chemosynthesis, which uses other sources of energy besides light energy. Giant tube worms, which live near hydrothermal vents at the bottom of the ocean, rely on chemosynthetic bacteria to fix carbon dioxide and produce sugars. These particular bacteria use hydrogen sulfide as an energy source through the following chemical reaction:

$$H_2S + CO_2 \rightarrow C_6H_{12}O_6 + H_2O + S$$

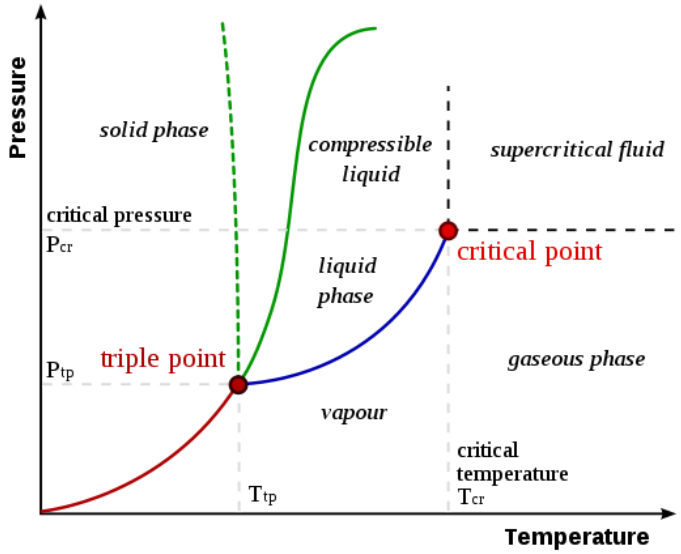
   A. **i.** Balance the above equation. **ii.** Write the corresponding oxidation and reduction half-reactions. Assume acidic conditions. **iii.** Determine the oxidation numbers for those elements that get oxidized and reduced.

   B. ΔG was found to be positive for this reaction. **i.** Circle which energy diagram corresponds with this reaction. This reaction cannot happen without special enzymes found in the bacteria that lower the activation energy. **ii.** On the diagram you circled in (**i.**), draw the corresponding energy curve for this reaction with an enzyme.



Name (Last, First): _____ ID Number: _____

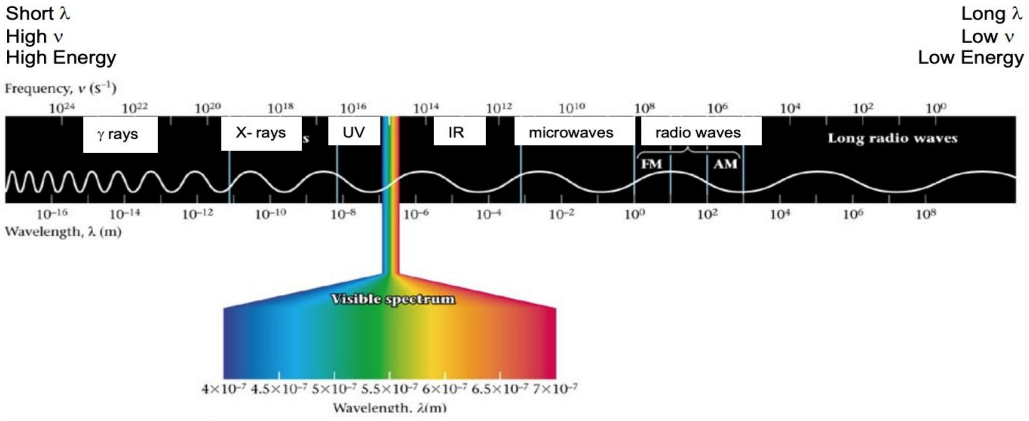
C. The water that comes out of seafloor hydrothermal vents is often heated by upwelling magma and is under immense pressure at those depths. The critical temperature of seawater near a vent is 400℃ and the critical pressure is 280.5 bars. If a particular vent issues water with a temperature of 464℃ and a pressure of 298.5 bars, what kind of state would this water exist in?



D. Many deep sea creatures produce their own light through the chemical process of bioluminescence. This reaction involves an enzyme which oxidizes a light-emitting pigment. As a result, energy due to the excitation of electrons in these pigments is released in the form of light.

This process is similar to the excitation of electrons in hydrogen atoms. Determine the wavelength of radiation emitted by hydrogen atoms upon electron transitions from n = 6 to n = 2. Is this transition in the visible light spectrum?

Given, $E = -E_0 / n^2$, where $E_0 = 2.18 \times 10^{-18}$ Joules



2. A marine oil spill is when liquid petroleum hydrocarbons are released into a marine ecosystem. Class C oils are heavy and sticky oils that adhere strongly to surfaces. They are not easily diluted, and they produce sticky films which can be detrimental to wildlife and make cleanup difficult. They are also prone to forming emulsions in water.

    a. Controlled burning can help reduce the amount of oil released in oil spills. The combustion reaction process used in controlled burning for the hydrocarbon octane is seen in Equation 1.

$$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$$

Equation 1

        i. Determine the enthalpy of combustion of 1 mol of octane by using the bond energies listed in Table 1. Report your answer in kJ/mol.

TABLE 8.4 Average Bond Enthalpies (kJ/mol)

Single Bonds							
C—H	413	N—H	391	O—H	463	F—F	155
C—C	348	N—N	163	O—O	146		
C—N	293	N—O	201	O—F	190	Cl—F	253
C—O	358	N—F	272	O—Cl	203	Cl—Cl	242
C—F	485	N—Cl	200	O—I	234		
C—Cl	328	N—Br	243			Br—F	237
C—Br	276			S—H	339	Br—Cl	218
C—I	240	H—H	436	S—F	327	Br—Br	193
C—S	259	H—F	567	S—Cl	253		
		H—Cl	431	S—Br	218	I—Cl	208
Si—H	323	H—Br	366	S—S	266	I—Br	175
Si—Si	226	H—I	299			I—I	151
Si—C	301						
Si—O	368						
Multiple Bonds							
C=C	614	N=N	418	O_2	495		
C≡C	839	N≡N	941				
C=N	615	N=O	607	S=O	523		
C≡N	891			S=S	418		
C=O	799						
C≡O	1072						

Table 1: Average bond enthalpies (kJ/mol)

ii. Is this reaction exothermic or endothermic? Give a brief justification for your answer (1 sentence).

iii. Determine the approximate heat released/used by burning 1.00 L of octane, given that the density of octane is 0.692 g/mL, and use the enthalpy of combustion of octane that was obtained in part a.i. If you were unable to obtain a ΔH^{o}_{comb} value in part a.i., use a ΔH^{o}_{comb} value of -1234 kJ/mol. Provide your answer in joules, up to 2 decimal places.

b. Imagine that 500L of octane was involved in the oil spill, and it reacted with 50 mol of oxygen (O_2).

   i. What is the limiting reactant?

   ii. Find the theoretical yield of carbon dioxide (in grams).

3. Dry air contains 21% Oxygen (O_2) (Oxygen is the second most abundant gas in the air.) Oxygen supports organisms—including animals live in a marine environment.

   a. A small portion of oxygen in the atmosphere dissolves into sea surface. Identify and explain the type of interaction between water molecules and dissolved oxygen molecules.

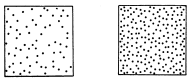
b. The solubility of O_2 is simultaneously influenced by temperature and its partial pressure in the air. The equation for the dissolution of oxygen gas is shown below.

$$O_{2\,(aq)} \rightleftharpoons O_{2\,(g)} \qquad K_{eq} = P_{O2}/[O_2(aq)] = 769.23\ L*atm/mol\ (at\ 298K)$$

i. Calculate the concentration of dissolved O_2 at sea surface at 298K (in ppm, 1 ppm=1 mg/L). Assuming the air pressure at sea level is equal to 1 atm; ignore other solutes in seawater; round your answer to two decimal places.

ii. Which do you think has a larger value, the concentration of O_2 you just calculated, or the actual sea surface O_2 concentration measured under the same temperature and pressure. Circle and explain your answer below. (calculated/measured)

c. Increased temperature causes an increase in kinetic energy. The higher kinetic energy causes more motion in the gas molecules which break intermolecular bonds and escape from solution. Considering this information, plot the O_2 concentration at the world's ocean surface corresponding to the density of dots on the world map given below. (For regions of higher O_2 concentration, draw more dots in that region.) Earth's rotation and revolution are not considered.



Low concentration High concentration

d. Sufficient O_2 concentration is crucial for the success of ongoing aquaculture along the coastline. Hydrogen peroxide, applied at very low concentration, can be used in aquaculture to increase dissolved oxygen in water.

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

i. Oxidizing agents are harmful to bacteria. Explain why hydrogen peroxide would be a good disinfectant in water. Use oxidation numbers in your explanation.

ii. Write a balanced net ionic reaction to illustrate the half-reaction when hydrogen peroxide functions as a reducing agent to produce oxygen in a basic environment.