

NAME: \_\_\_\_\_

As always, you must show all your work completely to receive full credit. For any answer involving writing, be concise and precise, and write legibly, i.e., take your time and think about how to compose your answer in a coherent manner before writing.

$h = 6.63 \times 10^{-34}$  J-sec;  $c = 3.00 \times 10^8$  m/sec; H-atom constant  $R = 2.18 \times 10^{-18}$  J;  $nm = 10^{-9}$  m

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1. The graph below shows a system's change from initial state A to final state Z. There are two possible paths indicated, one with an intermediate state at higher pressure, H, and one at a lower pressure, L. Via the questions below, prove that  $\Delta E$  is a function of state by showing that it has the same value whether path AHZ or path ALZ is via steps a-j. The system is two moles of a monatomic gas. [a-j, 3 pts. each.]

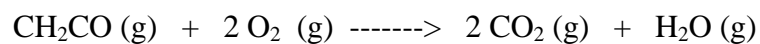
(a) Calculate the work of the system for AH

(b) Calculate the heat flow of the system for AH

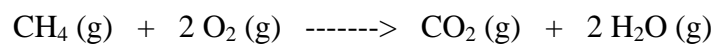
(c) Calculate the work of the system for HZ

- (d) Calculate the heat flow of the system for HZ
  
  
  
  
  
  
  
  
  
  
- (e) Calculate  $\Delta E$  for path AHZ
  
  
  
  
  
  
  
  
  
  
- (f) Calculate the work of the system for AL
  
  
  
  
  
  
  
  
  
  
- (g) Calculate the heat flow of the system for AL
  
  
  
  
  
  
  
  
  
  
- (h) Calculate the work of the system for LZ
  
  
  
  
  
  
  
  
  
  
- (i) Calculate the heat flow of the system for LZ
  
  
  
  
  
  
  
  
  
  
- (j) Calculate  $\Delta E$  for path ALZ, and compare this to your answer for part (e).

2. The measured enthalpy change for burning ketene (CH<sub>2</sub>CO)

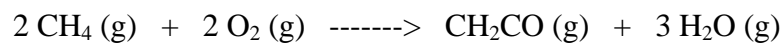


is  $\Delta H_1 = -981.1 \text{ kJ}$  at 25 °C. The enthalpy change for burning methane



is  $\Delta H_2 = -802.3 \text{ kJ}$  at 25 °C.

- (a) Using the above information, calculate the enthalpy change at 25 °C for the reaction:



using Hess's law. Be sure to show all your work and justifications!

- (b) The standard enthalpy of formation of H<sub>2</sub>O (g) is -241.82 kJ/mol, and that of CH<sub>4</sub> (g) is -74.81 kJ/mol. Using this information and your answer above, calculate the standard enthalpy of formation of CH<sub>2</sub>CO (g).

3. A quantity of 3.0 mol of an ideal gas at 25°C expands isothermally and reversibly from a pressure of 6.0 atm to 2.5 atm, calculate for this process

(a) the change in energy  $E$ , and the change in enthalpy  $H$

(b) the work of the system, and the heat flow of the system

4. One of the commonly used lines out of the argon ion laser in my research laboratory is the blue line at 514 nm.

(a) What is the energy of the radiation in Joules?

(b) Indicate whether the following types of photons are more energetic compared to that laser line, or less energetic.

- microwave:
- UV:
- x-ray:
- infrared:
- radiowave:

5. A number of experiments baffled scientists and catalyzed the development of quantum mechanics.
  - (a) For the photoelectric effect, describe the experimental setup and its results.
  - (b) How did Einstein explain these experimental results?
  - (c) State one of the fatal flaws in Bohr's explanation of the H-atom spectrum.
  - (d) In the blackbody radiation experiment, if the temperature is increased, does the wavelength maximum of the emission spectrum shift to higher or lower wavelengths?

6. The Paschen series of the hydrogen lines all have  $n=3$  in common.
- (a) Draw the the first two transitions (i.e., the two lowest energy spectral absorptions) in the Paschen series on an energy level diagram.
- (b) What is the energy (in Joules) for the third line in the series?

7. A world-class sprinter of 60 kg runs the 100 meters in 11.0 seconds.
- (a) What is the athlete's equivalent wavelength according to the deBroglie principle?
- (b) If we can measure the runner's speed to within 0.001 m/sec, what is the minimum error in measuring the finish-line position according to the Heisenberg principle (assume that the mass is known with zero error)?
8. Draw a graph with correctly marked axes for
- (a) The radial portion of the 3s wavefunction
- (b) The radial probability distribution of the 3p wavefunction.