3.091 OCW Scholar

Self-Asessment

Reactions and Kinetics

Supplemental Exam Problems for Study

Problem #4

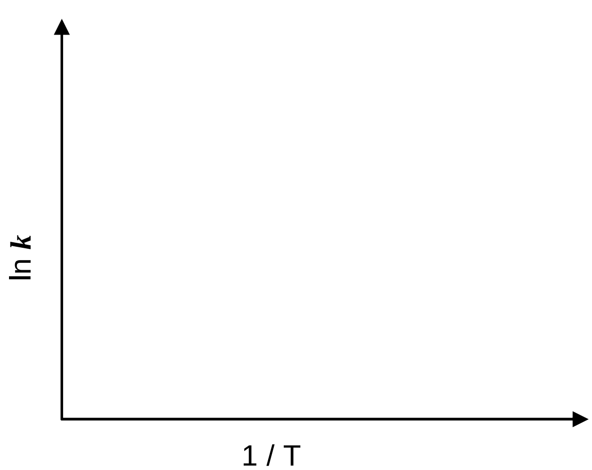
Acetaldehyde, CH_3CHO, will decompose into methane and carbon monoxide according to

$$CH_3CHO\ (g) \Rightarrow CH_4\ (g) + CO\ (g)$$

At 450ºC the rate of consumption of CH_3CHO is measured to vary with the concentration of CH_3CHO raised to the power 1.5.

(a) With a CH_3CHO concentration of 0.222 M, the rate of consumption of CH_3CHO at 450ºC is measured to be 3.33×10^{-3} Ms^{-1}. Calculate the rate of production of carbon monoxide when the concentration of CH_3CHO has fallen to 0.111 M.

(b) On the graph below, show how the specific chemical rate constant, *k*, varies with temperature when the above reaction is conducted ❶ in the absence of a catalyst; and ❷ in the presence of a catalyst. Label both lines so as to associate each with either ❶ or ❷. The diagram is not to be drawn to scale; however, you must pay attention to relative magnitudes.



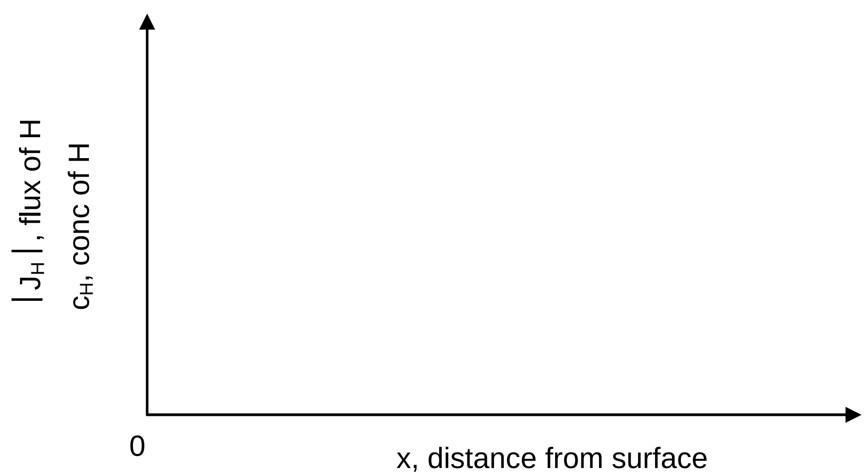
Problem #6

(a) A specimen of $LaNi_5$ containing hydrogen is placed in a vacuum furnace. After 1 hour, at what depth from the surface of the specimen has the concentration of hydrogen reached ⅓ the initial concentration? The diffusion coefficient of hydrogen in the alloy has a value of 3.091×10^{-6} cm^2 s^{-1}. Assume that the initial concentration of hydrogen is uniform throughout the specimen and that the concentration of hydrogen is maintained at zero in the vacuum furnace.

DATA: Error Function Values (given without regard as to whether you need these data to solve the problem)

for values of $\xi < 0.6$, use the approximation $erf(\xi) = \xi$; $erf(1.0) = 0.843$; $erf(2.0) = 0.998$

(b) On the same graph below, sketch the profiles of ❶ the concentration of hydrogen, c_H, and ❷ the absolute magnitude of the flux of hydrogen, $|J_H|$, in the near-surface region of the specimen of part (a) at time, t_1, where $0 < t_1 < 1$ h.



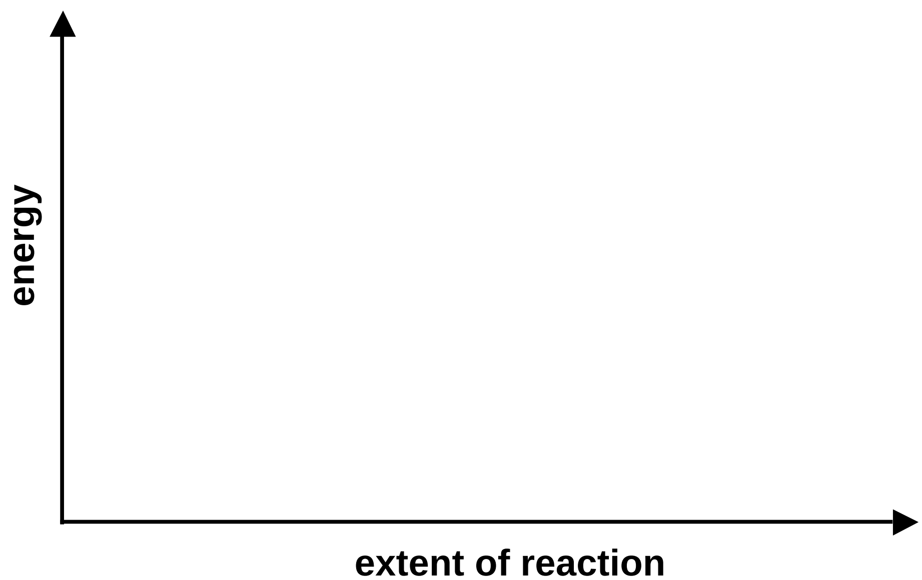
Problem #3

Azomethane, $CH_3N_2CH_3$, decomposes at 600 K to ethane, C_2H_6, and nitrogen, N_2. The reaction has been measured to be first order in azomethane.

(a) Write the rate law expression for the decomposition of azomethane.

(b) The value of the half-life, $t_{½}$, for this reaction has been measured to be 1920 s. How much of the initial amount of azomethane remains after 3.091 h? Express your answer as a ***fraction*** of the initial concentration, c_o, of azomethane.

(c) On the plot below, sketch the variation in energy (≈chemical potential) with extent of reaction for the decomposition of azomethane. Assume that the ratio of $E_a/\Delta E_{reaction} = -3$, where E_a represents the activation energy and $\Delta E_{reaction}$ the energy change of the reaction. Label E_a and $\Delta E_{reaction}$. Label the energy states of $CH_3N_2CH_3$, C_2H_6, and N_2.



(d) How does a catalyst change the ratio of the absolute value of $E_a/\Delta E_{reaction}$? Increase? Decrease? No change? Justify your answer by explaining what happens at the atomic level in the catalysis of a reaction in which all the reactants and products are gases.

Problem #4

There is a differential nitrogen pressure across a furnace wall made of steel measuring 2.22 mm in thickness. The concentration of nitrogen at the inner surface of the wall is held constant at 9.99 kg m^{-3}, while the concentration at the outer surface of the wall is held constant at 1.11 kg m^{-3}. The area of the wall is 3.33 m^2, and the diffusivity of nitrogen in steel at the furnace operating temperature is $D_N = 3.091 \times 10^{-10}$ m^2 s^{-1}.

(a) What is the total rate loss of nitrogen from the furnace at steady state? Express your answer in units of kg s^{-1}.

(b) If the steel of the wall were replaced with another steel of the identical composition but with a grain size 10× larger than that of the steel in part (a), how would the loss of nitrogen from the furnace change? Explain.

Problem #6

(a) The energy of vacancy formation, ΔH_v, in palladium (Pd) is 1.5 eV. At 888°C there is one vacancy for every million (10^6) atom sites. Is it possible, by simply raising the temperature and ***not exceeding the melting point of the metal***, to achieve a vacancy fraction of one vacancy for every thousand (10^3) atom sites?

(b) You are given two specimens of Pd, each of identical purity. Specimen ❶ has a grain size of 3.091 μm; specimen ❷ has a grain size of 444 μm. Which specimen will exhibit a higher rate of diffusion of hydrogen through it? Explain the reason for your choice.

Problem #11

Sulfuryl chloride, SO_2Cl_2, decomposes to SO_2 and Cl_2 according to

$$SO_2Cl_2(g) \rightarrow SO_2(g) + Cl_2(g).$$

The reaction is first order in SO_2Cl_2, and the value of the rate constant, k, is 2.2×10^{-5} s^{-1}.

(a) Calculate the initial rate of reaction when a reactor is charged with SO_2Cl_2 at a concentration of 0.11 mol L^{-1}. Express your answer in units of mol L^{-1} s^{-1}.

(b) Calculate how long it will take for the concentration of SO_2Cl_2 in the reactor in part (a) to fall to ¼ of its initial value. Express your answer in units of s.

Problem #12

(a) The diffusion coefficient of oxygen in silicon, D_O, has been measured to have the following values:

D_O (cm^2 s^{-1})	T (°C)
9.2×10^{-11}	1100
1.4×10^{-9}	1300

Show that in order to increase the value of D_O by a factor of 10× greater than it is at 1300°C would require raising the temperature above the melting point of silicon.

(b) Make a crude estimate showing that it is feasible to remove oxygen from a silicon ribbon of thickness 0.1 μm by exposing the ribbon to vacuum for 10 minutes at a temperature of 1100°C.