Reaction Kinetics II: Heterogeneous Systems

P109. A monolayer of N_2 molecules (effective area 0.165 nm^2) is adsorbed on the surface of 1.00 g of an Fe/Al_2O_3 catalyst at 77 K, the boiling point of liquid nitrogen. Upon warming, the nitrogen occupies 2.86 cm^3 at 0.0 °C and 760 Torr. What is the surface area of the catalyst? (12.68 m^2/g)

P110. A certain solid sample adsorbs 0.44 mg of CO when the pressure of the gas is 26.0 kPa and the temperature is 300 K. The mass of gas adsorbed when the pressure is 3.0 kPa and the temperature is 300 K is 0.19 mg. The Langmuir isotherm is known to describe the adsorption. Find the fractional coverage of the surface at the two pressures. ($\Theta_{26.0\ \mathrm{kPa}} = 0.828$, $\Theta_{3.0\ \mathrm{kPa}} = 0.358$)

P111. For how long on average would an H atom remain on a surface at 298 K if its desorption activation energy were

a. 15 kJ mol^{-1}, and ($4.259\cdot10^{-11}$ s)

b. 150 kJ mol^{-1}? ($1.966\cdot10^{13}$ s)

Take $\tau_0 = 0.10$ ps. For how long on average would the same atoms remain at 1000 K? ($6.075\cdot10^{-13}$ s and $6.846\cdot10^{-6}$ s)

P112. HI is very strongly adsorbed on gold but only slightly on platinum. Assume the adsorption follows the Langmuir isotherm. Predict the order of the HI decomposition reaction on each of the two metal surfaces. (Au: zeroth-order, Pt: first-order)

P113. The following data were obtained for the extent of adsorption, s, of acetone on charcoal from an aqueous solution of concentration c at 18 °C:

c /(mmol dm^{-3})	15.0	23.0	42.0	84.0	165	390	800
s /(mmol acetone/g charcoal)	0.60	0.75	1.05	1.50	2.15	3.50	5.10

Which isotherm fits these data best, Langmuir, Freundlich or Temkin? (Freundlich)

P114. In some catalytic reactions the products may adsorb more strongly than the reagent gas. This is the case *e.g.* in the catalytic decomposition of ammonia on Pt at 1000 °C.

a. As a first step in examining the kinetics of the process, show that the rate of ammonia decomposition should follow $\dfrac{\mathrm{d}\,p(NH_3)}{\mathrm{d}t} = -k_c \dfrac{p(NH_3)}{p(H_2)}$ in the limit of very strong adsorption of H_2. ($k_c = kK_{NH3}/K_{H2}$)

b. Show that plotting the $(1/t)\cdot\ln(p/p_0)$ values as a function of $(p-p_0)/t$ (where $p = p(NH_3)$) gives a straight line.

c. Check the rate law based on the data below and find k_c. ($k_c = 0.0258$ Torr/s)

t /s	0	30	60	100	160	200	250
$p(NH_3)$ /Torr	100	88	84	80	77	74	72