Chemistry 102 - Mechanisms and Equilibrium Problems

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(1) The reaction: $2\ H_2\ (g) + 2\ NO\ (g) \rightarrow N_2\ (g) + 2\ H_2O\ (g)$ is proposed to occur in a 3-step mechanism:

Step 1). $2\ NO\ (g)$	$\rightarrow\ N_2O_2\ (g)$	fast, equilibrated
Step 2). $N_2O_2\ (g) + H_2\ (g)$	$\rightarrow\ N_2O\ (g) + H_2O\ (g)$	fast, equilibrated
Step 3). $N_2O\ (g) + H_2\ (g)$	$\rightarrow\ H_2O\ (g) + N_2\ (g)$	slow

Determine the rate expression (law) for the overall reaction.

(a) $k[N_2O][H_2]$ (b) $k\dfrac{[NO]^2[H_2]}{[H_2O][N_2]}$ (c) $k\dfrac{[N_2O_2][H_2]}{[H_2O]}$

(d) $k[NO]^2[H]$ (e) $k\dfrac{[NO]^2[H_2]^2}{[H_2O]}$

(2) The appropriate expression for the equilibrium constant, K, of the reaction $CH_4\ (l) + 2\ O_2\ (g) \rightarrow CO_2\ (g) + 2\ H_2O\ (g)$ is

(a) $\dfrac{[CH_4][O_2]^2}{[CO_2][H_2O]^2}$ (b) $\dfrac{[CO_2][H_2O]^2}{[CH_4][O_2]^2}$

(c) $\dfrac{[CO_2][H_2O]^2}{[O_2]^2}$ (d) $\dfrac{[O_2]^2}{[CO_2][H_2O]^2}$ (e) $\dfrac{[CH_4][O_2]}{[CO_2][H_2O]}$

(3) The complex reaction describing the depletion of ozone in the upper atmosphere is given by: $2\ O_3\ (g) \rightarrow 3\ O_2\ (g)$. The following mechanism (one of many) has been proposed:

$2\ NO\ (g) + O_2\ (g)$	$\rightarrow\ 2\ NO_2\ (g)$	fast, equilibrated
$2\ NO_2\ (g) + 2\ O_3\ (g)$	$\rightarrow\ 4\ O_2\ (g) + 2\ NO\ (g)$	slow

Which species is catalyst and which species is intermediate (respectively)?

(a) NO, NO_2 (b) NO_2, NO (c) O_2, O_3 (d) O_2, NO_2 (e) O_3, O_2

(4) The chemical reaction $CO_2 \rightarrow CO(g) + \frac{1}{2}\ O_2\ (g)$ has enthalpy change H = +283 kJ/moL. Which of the following changes would cause the production of more carbon monoxide?

1. raise the pressure 2. remove oxygen 3. raise the temperature

(a) 3, 2 (b) 2,1 (c) 1 only (d) 2 only (e) 3 only

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(5) The reaction $N_2(g) + 3\,H_2(g) \rightarrow 2\,NH_3(g)$ occurs in a closed vessel. Initially 2.300 atm of nitrogen and 3.600 atm hydrogen are introduced into the reaction chamber. If, at equilibrium, the concentration of hydrogen is 3.501 atm, determine the equilibrium constant.

(a) 0.09900 (b) 0.03300 (c) 9.319×10^{-3} (d) 4.478×10^{-5} (e) 0.1911

(6) For the reaction, $H_2(g) + Br_2(g) \dashrightarrow 2\,HBr(g)$, $K_c = 3.5 \times 10^4$ at 1495 K.

If the initial concentrations of H_2, Br_2, and HBr are 0.1 M, 0.3 M, and 50 M respectively, what are the equilibrium concentrations of each component? Note: this is not a practical problem – it is purely hypothetical for problem solving purposes.

(6)

$$H_2 + Br_2 \rightleftharpoons 2HBr$$

0.1	0.3	50
$0.1 + x$	$0.3 + x$	$50 - 2x$

$$\frac{((50)-2x)^2}{(0.1+x)(0.3+x)} = 3.5 \times 10^4$$

$34996x^2 - 14200x + 1450 = 0$

$x = 0.0845$

$[H_2] = 0.1845\,M$

$[Br_2] = 0.3845$

$[HBr] = 49.831$

(5)

$$N_2 + 3H_2 \rightarrow 2NH_3$$

I	2.3	3.6	0
C	$-x$	$-3x$	$2x$
E	$2.3 - x$	3.501	$2x$

$3x = 0.099 \rightarrow x = 0.033$

$P_{N_2} = 2.267$

$P_{H_2} = 3.501$

$P_{NH_3} = 0.066$

$K_{eq} = 4.478 \times 10^{-5}$