EQUILIBRIUM REVIEW
ANSWER KEY

EQUILIBRIUM IS DYNAMIC – THE FORWARD AND REVERSE RATES ARE ALWAYS OCCURRING AT EQUAL RATES. BECAUSE RATES ARE EQUAL, $[CrO_4^{2-}]$ REMAINS CONSTANT.

② A) BECAUSE FORWARD AND REVERSE REACTIONS ARE ALWAYS OCCURRING.
B) MACROSCOPIC PROPERTIES ARE CONSTANT.

③ IF AN EQUILIBRIUM IS SUBJECTED TO A CHANGE, PROCESSES OCCUR TO COUNTERACT THAT CHANGE UNTIL A NEW EQUILIBRIUM IS ESTABLISHED.

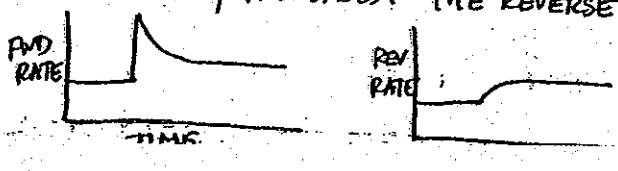
④ AN EXAMPLE OF A MACROSCOPIC PROPERTY IS COLOUR. COLOUR IS CONSTANT AT EQUILIBRIUM BECAUSE THE SUBSTANCE THAT HAS THE COLOUR REMAINS CONSTANT IN AMOUNT AND/OR CONCENTRATION.

⑤ A) ENTHALPY IS DECREASING BECAUSE THE FWD RXN IS EXOTHERMIC
B) ENTROPY IS MINIMIZED IN THE FWD DIREC. BECAUSE THERE ARE LESS PRODUCT GAS MOLECULES THAN REACTANT GAS MOLECULES. THE REACTION WILL COME TO EQUILIBRIUM.

⑥ ENTHALPY IS INCREASING IN THE FWD DIRECTION
∴ DECREASING IN THE REVERSE DIRECTION
ENTROPY IS INCREASING IN THE FWD DIRECTION
∴ THE SYSTEM WILL COME TO EQUILIBRIUM BECAUSE SYSTEMS TEND TOWARD DECREASING ENTHALPY AND INCREASING ENTROPY AND THEY OFFSET EACH OTHER.

⑦ A) ↑ TEMP ∴ SHIFT LEFT ∴ MOLES OF CH_3OH DECREASE
B) ↑ $[CO]$ ∴ SHIFT RIGHT ∴ MOLES OF CH_3OH INCREASE
C) ↓ $[H_2]$ ∴ SHIFT LEFT ∴ MOLES OF CH_3OH DECREASE
D) ↑ PRESSURE ∴ SHIFT RIGHT ∴ MOLES OF CH_3OH INCREASE
E) ↑ $[CH_3OH]$ ∴ SHIFT LEFT BUT SLIGHT ↑ $[CH_3OH]$ ∴ MOLES OF CH_3OH INCREASE
F) ↓ $[CH_3OH]$ ∴ SHIFT RIGHT BUT SLIGHT ↓ $[CH_3OH]$ ∴ MOLES OF CH_3OH DECREASE

CO ADDED, FORWARD RATE INCREASES IMMEDIATELY, THEN STARTS TO DECREASE AGAIN BUT OVERALL SLIGHTLY INCREASES. THE REVERSE RATE SLOWLY SLIGHTLY INCREASES.



ONCE FWD + REV RATES BECOME EQUAL AGAIN (BOTH SLIGHT INC), A NEW EQUILIBRIUM IS ESTABLISHED.

(9) $K_{eq} = \frac{[NO_2]^2}{[N_2O_4]}$ A) $K_{eq\ AT\ 5\ SECS} = \frac{(0.80)^2}{0.90} = 0.71$

A) $K_{eq\ AT\ 15\ SECS} = \frac{(0.84)^2}{0.88} = 0.80$ $K_{eq\ AT\ 25\ SECS} = \frac{(0.86)^2}{0.92} = 0.80$

B) AT 10s, TEMPERATURE OF THE SYSTEM WAS INCREASED. THIS IS SUPPORTED BY A DIFFERENT K_{eq} VALUE BEFORE THE CHANGE COMPARED TO AFTER WHICH SUPPORTS A TEMP CHANGE.
AT 10s, $[NO_2]\uparrow$ AND $[N_2O_4]\downarrow$, A SHIFT IN THE FORWARD AND ENDOTHERMIC DIRECTION. A TEMP INC. SHIFTS IN THE ENDOTHERMIC DIRECTION

C) AT 20s, THE PRESSURE OF THE SYSTEM INCREASED. THIS IS SUPPORTED BY INSTANT INCREASES IN ALL GAS CONCS FOLLOWED BY ANOTHER ↑ IN $[N_2O_4]$, THE SIDE WITH FEWER GAS MOLECULES. ALSO, K_{eq} REMAINS UNCHANGED WHICH SUPPORTS A PRESSURE CHANGE.

(10) A) AT t_1, HI IS ADDED TO THE SYSTEM.
B) AT t_2, PRESSURE IS DECREASED (VOLUME INCREASED)
C) AT t_3, TEMPERATURE IS INCREASED.
D) AT t_4, I_2 IS REMOVED FROM THE SYSTEM

(11)

	$2NO_{(g)}$	+ $Cl_{2(g)}$	⇌ $2NOCl_{(g)}$
I	0.90M	0.60M	0
C	−0.56	−0.28	+0.56
E	0.34	0.32	0.56

$[NO] = \frac{0.90\ mol}{1.0\ L} = 0.90M$

$K_{eq} = \frac{[NOCl]^2}{[NO]^2[Cl_2]} = \frac{(0.56)^2}{(0.34)^2(0.32)} = \underline{8.5}$

(12)

	$H_{2(g)}$	+ $I_{2(g)}$	⇌ $2HI_{(g)}$
I	0.200M	0.100M	0
C	−0.080	−0.080	+0.160M
E	0.120	0.020	0.160M

$[H_2] = \frac{0.400\ mol}{2.00\ L} = 0.200M$

$[I_2] = \frac{0.200\ mol}{2.00\ L} = 0.100M$

$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = \frac{(0.160)^2}{(0.120)(0.020)} = 10.7 = \frac{11}{2}$

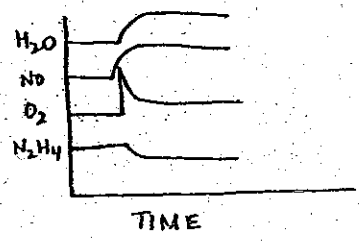
(13) A) $K_{eq} = \dfrac{[NO_2]^2}{[NO]^2[O_2]}$

B) $K_{eq} = \dfrac{[NO_2]^2}{[NO]^2(1.6)} = 6.45\times10^5$

$[NO_2] > [NO]$ IF $K_{eq} = 6.45\times10^5$

(14) A) O_2, NO, H_2O

B) N_2H_4



(15) $SO_{3(g)} + NO_{(g)} \rightleftharpoons NO_{2(g)} + SO_{2(g)}$

I	0.100M	0.100M	0	0
C	$-x$	$-x$	$+x$	$+x$
E	$0.100-x$	$0.100-x$	x	x

$[SO_3] = \dfrac{0.100\text{ mol}}{1.00\text{ L}} = 0.100\text{ M}$

LET $x = \Delta[SO_3]$

$K_{eq} = \dfrac{[NO_2][SO_2]}{[SO_3][NO]}$ $\quad 0.500 = \dfrac{x^2}{(0.100-x)^2}$ $\quad \sqrt{0.500} = \sqrt{\dfrac{x^2}{(0.100-x)^2}}$

$0.7071 = \dfrac{x}{0.100-x}$ $\quad (0.7071)(0.100-x) = x$ $\quad 0.07071 - 0.7071x = x$

$0.07071 = 1.7071x$ $\quad \therefore x = 0.04142$

$[SO_2]_{eq} = 0.0414\text{ M}$

(16) $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$

I	0.0400M	0.0400M	0
C	$-x$	$-x$	$+2x$
E	$0.0400-x$	$0.0400-x$	$2x$

LET $x = \Delta[N_2]$

$[N_2] = \dfrac{0.200\text{ mol}}{5.00\text{ L}} = 0.0400\text{ M}$

$[O_2] = \dfrac{0.200\text{ mol}}{5.00\text{ L}} = 0.0400\text{ M}$

$K_{eq} = \dfrac{[NO]^2}{[N_2][O_2]}$ $\quad \sqrt{0.0081} = \sqrt{\dfrac{(2x)^2}{(0.0400-x)^2}}$ $\quad 0.090 = \dfrac{2x}{0.0400-x}$ $\quad 0.0036 - 0.090x = 2x$

$.036 = 2.09x$ $\quad \therefore x = 0.00172$

$[NO]_{eq} = 2x = 2(0.00172) = 0.0034\text{ M}$

$[N_2] = [O_2]_{eq} = 0.0400 - x$

$= 0.0400 - 0.00172$

$= 0.0383\text{ M}$

$0.0400 - 0.00172 = 0.03828$

(17) $2NO_{(g)} + Br_{2(g)} \rightleftharpoons 2NOBr_{(g)}$

I	0	0	x	LET $x = [NOBr]_i$
C	+0.0800M	+0.0400M	−0.0800M	
E	0.0800M	0.0400M	$x-0.0800$M	

$K_{eq} = \frac{[NOBr]^2}{[NO]^2[Br_2]}$ $\quad 1.0\times10^2 = \frac{(x-0.0800)^2}{(0.0800)^2(0.0400)}$

$\sqrt{0.0256} = \sqrt{(x-0.0800)^2}$ $\quad [NOBr]_i = 0.24\,M$

$0.16 = x - 0.0800$ $\quad$ mol NOBr $= (0.24)(2.00L) = 0.48$ mol

$x = 0.24$

(18) $2HCl \rightleftharpoons H_2 + Cl_2$ $\quad$ LET $x = [H_2]_i$

I	0	x	x	
C	+0.240	−0.120	−0.120	
E	0.240	$x-0.120$	$x-0.120$	

$K_{eq} = \frac{[H_2][Cl_2]}{[HCl]^2}$ $\quad 0.700 = \frac{(x-0.120)^2}{(0.240)^2}$

$0.04032 = (x-0.120)^2$

$[H_2]_i = [Cl_2]_i = 0.321\,M$

$0.2008 = x - 0.120$

$0.3208 = x.$

(19) $K_{eq} = \frac{[CO][H_2]^3}{[CH_4][H_2O]}$ $\quad$ TRIAL $K_{eq} = \frac{(0.320)(0.780)^3}{(0.360)(0.0800)} = 5.27$

$K_{eq} = 6.58$ $\quad$ TRIAL $K_{eq} < K_{eq}$ ∴ RXN SHIFTS RIGHT TO GET TO EQUILIBRIUM

∴ $[CH_4]$ DECREASES.

(20) AS TEMP ↑, KEQ ↑

K_{eq} ↑ IS SHIFT TO PRODUCT SIDE

TEMP ↑ IS SHIFT TO ENDO SIDE

∴ FWD RXN MUST BE ENDOTHERMIC

(21) $K_{eq} = \frac{[HI]^2}{[H_2][I_2]}$ $\quad K_{eq} = 64$

Let x = moles of each substance

TRIAL $K_{eq} = \frac{x^2}{x \cdot x} = \frac{x \cancel{x}}{\cancel{x} x} = 1$

SINCE TRIAL $K_{eq} < K_{eq}$, RXN SHIFTS RIGHT.