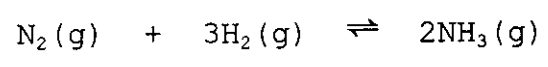


50 = %

Name: _____

SCH 4U - Quantitative Equilibrium Test

1. The following gas phase equilibrium was carried out in an 800 mL flask at a constant temperature:



Injection of NH_3 into an empty flask produces an initial concentration of 0.500 mol/L. After equilibrium has been reached (some time has passed), the concentration of NH_3 has dropped to a final value of 0.200 mol/L. Use this information to determine the K_{eq} value for this equilibrium reaction at the given temperature.

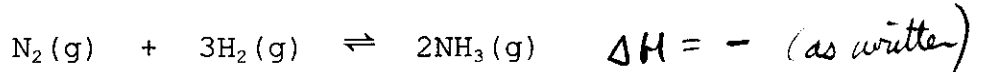
	N_2	+	$3H_2$	\rightleftharpoons	$2NH_3$	800 mL ✓
initial []	0		0		0.500 mol/L ✓	
initial amount	0		0		0.400 mol ✓	
final amount	0.12 mol ✓		0.36 mol ✓		0.400 - 0.24 ✓ = 0.16 mol ✓	
final []	0.15 mol/L		0.45 mol/L ✓		0.200 mol/L ✓	

$$K_{eq} = \frac{[NH_3]^2}{[N_2][H_2]^3} \quad \checkmark$$

$$K_{eq} = \frac{(0.200)^2}{(0.15)(0.45)^3}$$

$$K_{eq} = 2.93 \quad \checkmark$$

2. Using the information from the last question, construct a graph for ammonia equilibrium. Assume that equilibrium is reached at $t = 8$ minutes. Now at $t = 15$ minutes add the effect of an increase in temperature. Show a complete Le Chatelier's Principle calculation to get the direction correct. Show a shift in the graph that corresponds to this direction. The size of the shift cannot be calculated (use anything that you like). Note however, that the stoichiometry in this reaction will affect the relative size of the individual shifts for N_2 , H_2 and NH_3 . Show a return to equilibrium by $t = 20$ minutes. I would recommend a concentration axis scale division of 0.05 per division.



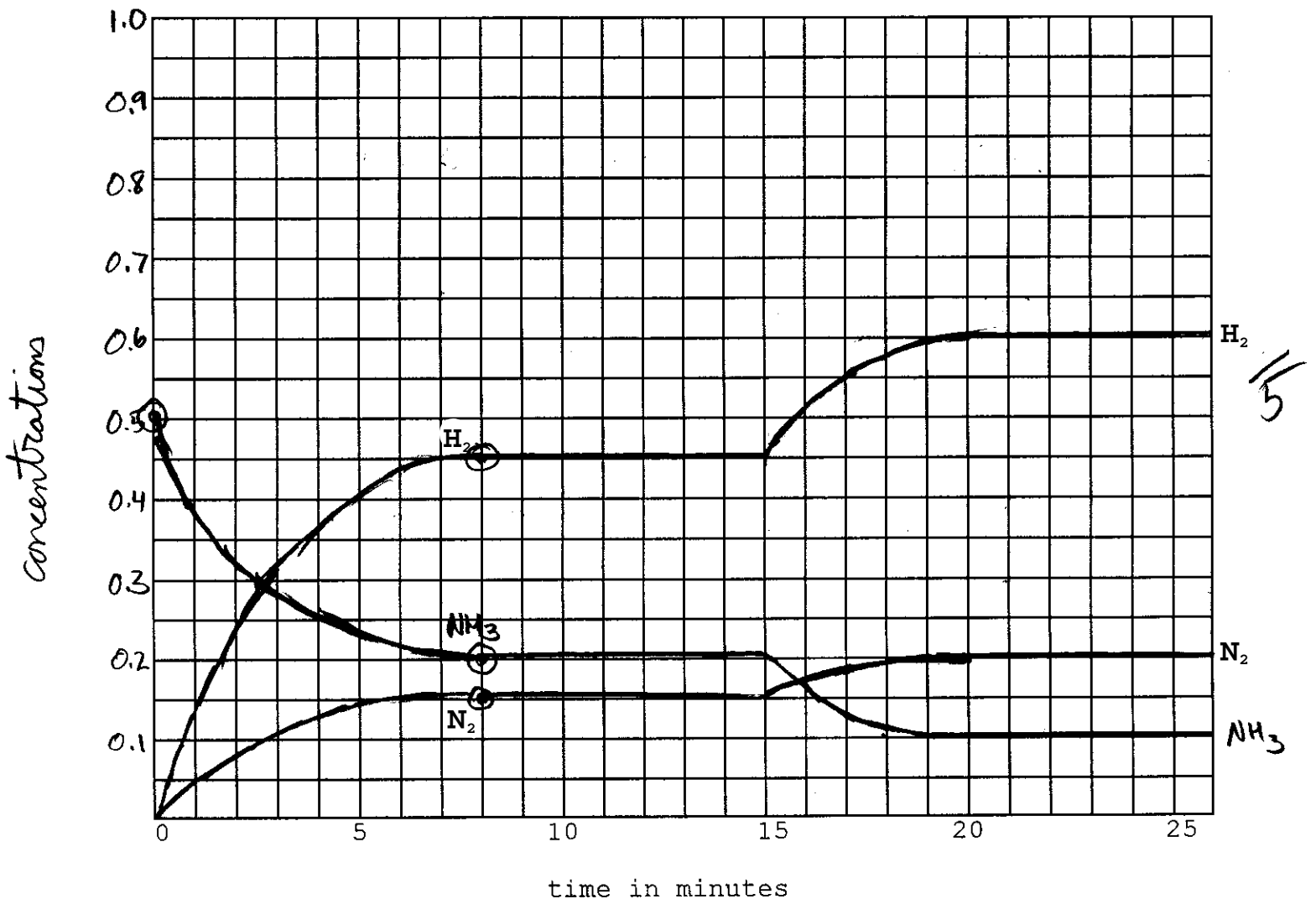
Stress: $\uparrow Q$ ✓

Response: $\downarrow Q$

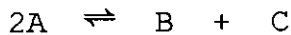
How: *endothermic reaction* ✓

Direction: *left* ✓

Effect: $\uparrow [N_2]$ $\times 1$, $\uparrow [H_2]$ $\times 3$, $\downarrow [NH_3]$ $\times 2$ ✓



3. For the gas phase equilibrium:



An initial concentration of A of 0.200 mol/L in a 5.00 L flask is allowed to equilibrate. If the equilibrium constant for this reaction is $K_{eq} = 4.00$, what will the final concentrations of all three gases become at the final equilibrium state?
 ↑ Is it possible that you need a variable here??

Show your work
(not just in table)

	2A	⇌	B	+	C
initial []	0.200 mol/L ✓		/		/
initial amount	1 mol ✓		∅		∅ ✓
final amount	1 - 2x ✓		x ✓		x ✓
final []	$\frac{1-2x}{5}$ ✓		$\frac{x}{5}$ ✓		$\frac{x}{5}$ ✓

5.00 L ✓

Let x represent the amount of B or C that forms ✓

$$K_{eq} = \frac{[B][C]}{[A]^2} \checkmark$$

$$4.00 = \frac{\left(\frac{x}{5}\right)\left(\frac{x}{5}\right)}{\left(\frac{1-2x}{5}\right)\left(\frac{1-2x}{5}\right)} \checkmark$$

$$4.00 = \left(\frac{x}{5}\right)\left(\frac{x}{5}\right)\left(\frac{5}{1-2x}\right)\left(\frac{5}{1-2x}\right)$$

$$4.00(4x^2 - 4x + 1) = x^2$$

$$16x^2 - 16x + 4 = x^2$$

$$15x^2 - 16x + 4 = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\rightarrow x = \frac{16 \pm \sqrt{16^2 - 4(15)(4)}}{2(15)}$$

$$x = \frac{16 \pm 4}{30}$$

$x = 0.6$ or $x = 0.4$ ✓
 extraneous
 (too large)

$$\therefore [A] = \frac{1-2x}{5} \quad [C] = 0.08$$

$$= \frac{1-2(0.4)}{5} \checkmark$$

$$= 0.04$$

$$[B] = \frac{x}{5}$$

$$= \frac{0.4}{5} \checkmark$$

$$= 0.08$$

15

4. For the gas phase equilibrium:



equilibrium concentrations are found to be:

$$\begin{aligned} [A] &= 0.200 \text{ mol/L} \\ [B] &= 0.400 \text{ mol/L} \\ [C] &= 0.900 \text{ mol/L} \end{aligned}$$

$$K_{eq} = \frac{[C]^3}{[A]^2[B]} \rightarrow K_{eq} = 45.6$$

$$K_{eq} = \frac{(0.9)^3}{(0.2)^2(0.4)}$$

Now to this equilibrium, a substantial amount of C is injected, such that the [A] rises to 0.800 mol/L once equilibrium has been reestablished. If the volume of the flask is fixed at 25.0 L, determine the amount of C that was injected. Believe it or not, you have enough information to solve this problem. The stated concentrations above are at equilibrium, the injection of C then creates initial conditions, which then lead to final concentrations such that [A] rises to 0.800 mol/L

	2A	+	B	\rightleftharpoons	3C	25.0L
initial []	0.200 mol/L	✓	0.400 mol/L		$(0.900 + \frac{x}{25})$ mol/L	
initial amount	5 mol	✓	10 mol		$(22.5 + x)$ mol	
final amount	$5 + 15$ = 20 mol	✓	$10 + 7.5$ = 17.5 mol		$22.5 + x - 22.5$ = x	
final []	0.800 mol/L	✓	0.700 mol/L	✓	$\frac{x}{25}$	

Let x represent the amount of C injected ✓

$$K_{eq} = \frac{[C]^3}{[A]^2[B]} \rightarrow 2.733 = \frac{x}{25}$$

$$45.6 = \frac{\left(\frac{x}{25}\right)^3}{(0.8)^2(0.7)}$$

$$20.416 = \left(\frac{x}{25}\right)^3$$

$$\frac{x}{25} = 2.733$$

$$x = 68.32 \text{ mol} \checkmark$$