Name: ________________

Equilibrium Test - General Principles and Gas Phase Calculations!!

1. Provide the six criteria required in order for a system to be considered an equilibrium system.

- reversable physical or chemical change ✓
- forward reaction rate equals reverse reaction rate ✓
- consistency of observable properties ✓
- closed system ✓
- can start with reactants only, products only or any ~~thereof~~ combination ✓
- continuous activity at the molecular level ✓

2. For the equilibrium show below, what would the effect be on the equilibrium constant (Keq) if the temperature is decreased:

$$2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g) \quad \Delta H = + \text{ as written}$$ ✓

S: ↓Q ✓

R: ↑Q

H: exothermic reaction ✓

D: shifts left ✓

E: ↑[NH_3], ↓[N_2], ↓[H_2] ✓ ∵ $keq = \frac{\downarrow[N_2]\downarrow[H_2]^3}{\uparrow[NH_3]^2}$ ✓

∴ keq ↓

3. How can the reactant concentration be maximized using the stress of change in temperature or change in volume?

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \quad \Delta H° = \text{~~X~~} + \text{ as written}$$

Method One:	Method Two:
D: shift left ✓ H: exothermic reaction ✓ R: ↑Q ✓ S: ↓Q ∴ reduce temperature ✓	D: shift left ✓ H: make less moles of gas R: ↓P ✓ S: ↑P ∴ reduce volume ✓

4. For this gas phase equilibrium in a **25.0 L** flask, the initial concentrations of nitrogen, hydrogen and ammonia were found to be 0.0044 mol/L, 0.0132 mol/L and 0.0312 mol/L. To this equilibrium, a change in temperature increases the [$NH_3(g)$] to 0.0352 mol/L. Use this information to determine the final concentrations of the other two gases and the equilibrium constant at the final temperature.

	N_2 +	$3H_2$ ⇌	$2NH_3$
Initial [ ]	① 0.0044 mol/L	② 0.0132 mol/L	③ 0.0312 mol/L ✓
Initial Amount	0.11 mol	0.33 mol	0.78 mol ✓
Final Amount	0.11 − 0.05 ✓ = 0.06 mol ✓ ⑧	⑦ 0.33 − 0.15 ✓ ⑥ = 0.18 mol ✓ ⑨	0.78 + 0.10 ✓ ⑤ = 0.88 mol ✓ ④
Final [ ]	0.0024 mol/L ✓	0.0072 mol/L	0.0352 mol/L ✓

25.0 L flask

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

$$K_{eq} = \frac{(0.0352)^2}{(0.0024)(0.0072)^3}$$

$$K_{eq} = 1383173$$ ✓

5. Phosgene gas (a particularly poisonous gas) is produced through the equilibrium reaction show in the table. Equilibrium concentrations in an **8.0 L** flask are found to be:

[CO] = **0.400 mol/L**

[Cl_2] = **1.00 mol/L**

[$COCl_2$] = **0.250 mol/L**

What will these concentrations become if the flask volume is doubled (i.e **16.0 L**). Please include an L.C.P. determination as a part of your answer.

		CO	+	Cl_2	⇌	$COCl_2$
8.0L	Initial [ ]	0.400 mol/L		1.00 mol/L		0.250 mol/L ✓
	Initial Amount	3.2 mol		8.00 mol		2.00 mol ✓
16.0L ✓	Final Amount	3.2 + x ✓		8 + x ✓		2 − x ✓
	Final [ ]	$\frac{3.2+x}{16}$		$\frac{8+x}{16}$		$\frac{2-x}{16}$ ✓

S: ↓P ✓
R: ↑P
H: make more gas ✓
D: shift left ✓
E: ↓[CO], ↓[Cl_2], ↓[$COCl_2$]

$K_{eq} = \frac{[COCl_2]}{[CO][Cl_2]}$ ✓

$K_{eq} = \frac{0.250}{(0.400)(1.00)}$

$K_{eq} = 0.625$ ✓

✓ Let x represent the amount of $COCl_2$ that decomposes

$K_{eq} = \frac{[COCl_2]}{[CO][Cl_2]}$ ✓

$0.625 = \frac{\frac{2-x}{16}}{\left(\frac{3.2+x}{16}\right)\left(\frac{8+x}{16}\right)}$

$0.625 = \left(\frac{2-x}{16}\right)\left(\frac{16}{3.2+x}\right)\left(\frac{16}{8+x}\right)$

$0.625(3.2+x)(8+x) = 16(2-x)$

$0.625(x^2 + 11.2x + 25.6) = 32 - 16x$

$0.625x^2 + 7x + 16 = 32 - 16x$

$0.625x^2 + 23x - 16 = 0$

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

$x = \frac{-23 \pm \sqrt{23^2 - 4(0.625)(-16)}}{2(0.625)}$

→ $x = \frac{-23 \pm 23.854}{1.25}$

$x = -37.48$ too "large" ∴ extraneous or $x = 0.683$ ✓✓

∴ $[CO] = \frac{3.2+x}{16} = \frac{3.2+0.683}{16} = 0.2427$ mol/L ✓

$[Cl_2] = \frac{8+x}{16} = \frac{8+0.683}{16} = 0.5427$ mol/L ✓

$[COCl_2] = \frac{2-x}{16} = \frac{2-0.683}{16} = 0.0823$ mol/L ✓

6. For this gas phase equilibrium shown in the table, **8 mol of C** is place in a **4 L flask** and allowed to equilibriate. If the equilibrium constant for this reaction is **2.50**, what are the final concentrations for all three gases?

	A +	B ⇌	C
Initial [ ]	/	/	/
Initial Amount	Ø	Ø	8 mol ✓
Final Amount	x ✓	x	8 − x ✓
Final [ ]	$\frac{x}{4}$	$\frac{x}{4}$	$\frac{8-x}{4}$ ✓

✓ 4 L flask

let x represent the amount of A that forms ✓

$$K_{eq} = \frac{[C]}{[A][B]}$$ ✓

$$2.50 = \frac{\frac{8-x}{4}}{\left(\frac{x}{4}\right)\left(\frac{x}{4}\right)}$$

$$2.50 = \left(\frac{8-x}{4}\right)\left(\frac{4}{x}\right)\left(\frac{4}{x}\right)$$

$$2.50x^2 = 32 - 4x$$

$$0 = 2.50x^2 + 4x - 32$$

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

$$x = \frac{-4 \pm \sqrt{4^2-4(2.50)(-32)}}{2(2.50)}$$

$$x = \frac{-4 \pm 18.33}{5}$$

∴ $x = \sout{-4.466}$ or $x = 2.866$

extraneous
cannot be neg. ✓✓

∴ $[A] = \frac{x}{4}$

$[A] = \frac{2.866}{4}$ ✓

$[A] = 0.7165$ mol/L

∴ $[B] = 0.7165$ mol/L

∴ $[C] = \frac{8-x}{4}$ ✓

$[C] = \frac{8-2.866}{4}$

$[C] = 1.283$ mol/L

7. The graph shown below is for the gas phase equilibrium:

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

Please indicate:

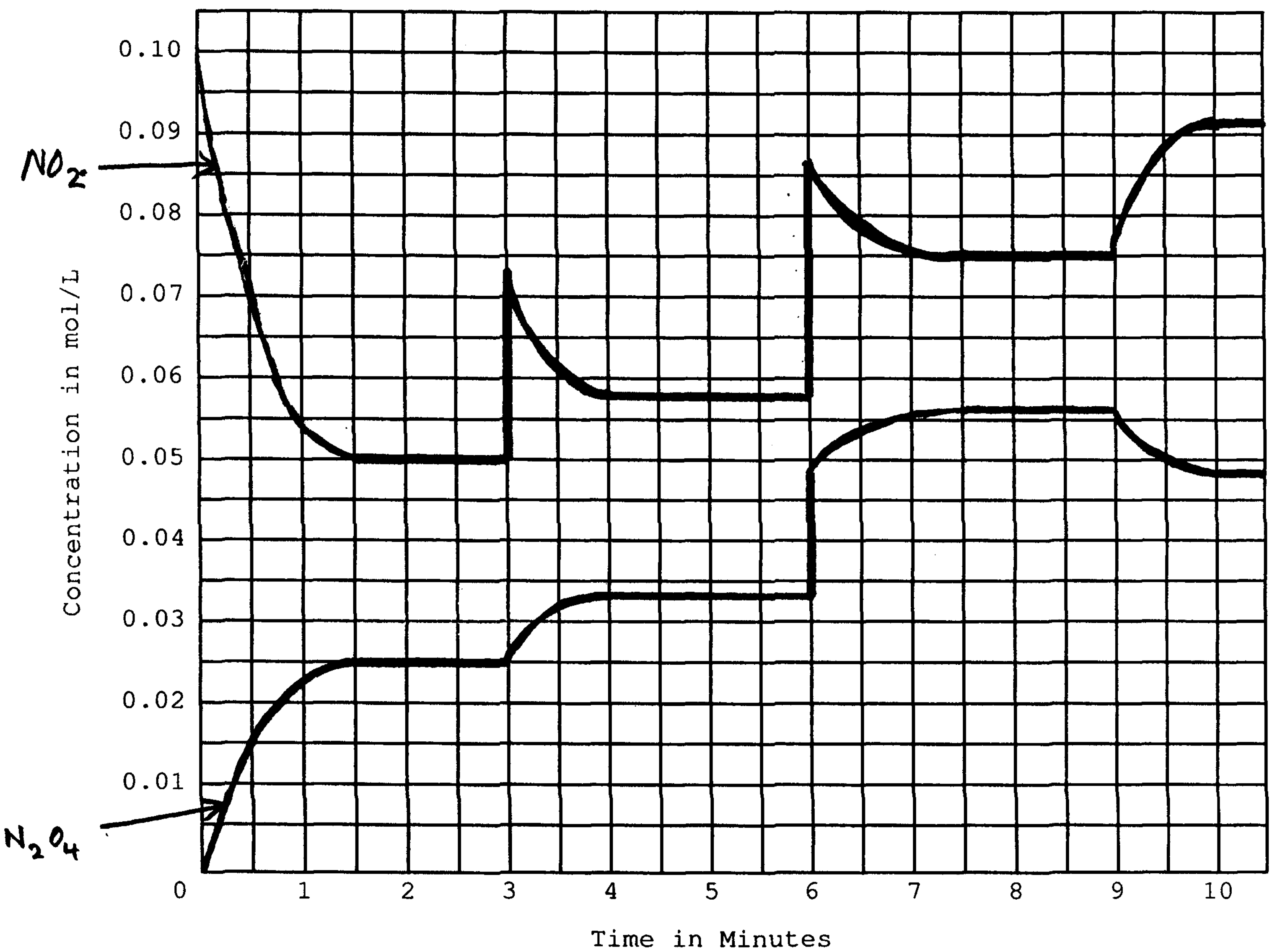
a) when equilibrium is first reached? 1.5 minutes

b) what is happening at 3 minutes? injection of NO_2

c) when equilibrium is re-established? 4 minutes

d) what is happening at 6 minutes volume is decreased (to ½)

e) what is happening at 9 minutes temperature is increased



Provide clear evidence to support your answer for e) above using numerical verification. Explain briefly.

$K_{eq} = \frac{[N_2O_4]}{[NO_2]^2}$

@t=2s: $K_{eq} = \frac{0.025}{(0.05)^2}$, $K_{eq} = 10$

@t=5s: $K_{eq} = \frac{0.033}{(0.058)^2}$, $K_{eq} = 9.8$

@t=8s: $K_{eq} = \frac{0.056}{(0.075)^2}$, $K_{eq} = 9.95$

similar ∴ same temp

@t=10s: $K_{eq} = \frac{0.48}{(0.92)^2}$, $K_{eq} = 0.567$

different ∴ different temp

Since Keq is affected by temperature only, a change in Keq shows a change in temp.