Dougherty Valley HS Chemistry

Name KEY

Equilibrium

Period _____ Date _____

UNIT QUIZ • PRACTICE

- You may use a pencil, eraser, and scientific calculator to complete the test.
- You will be given a periodic table. No other resources are allowed.
- Please transfer your answers for Sections 1, 2, and 3 onto the Answer Document. Work for these questions will not be graded. However, sufficient and appropriate work must be shown for the Free Response questions in order to receive full credit.

SECTION 1: A, B, OR C. For each of the following descriptions, determine whether the reaction shifts to the right, shifts to the left, or has no shift from its equilibrium position. (1 point each)

NH_4NO_3 (s) ⇆ 2 H_2O (g) + N_2O (g) + heat

	(A)	(B)	(C)
1. A catalyst is added. NO Δ, JUST MOVES FASTER	Left	Right	No Shift
2. N_2O (g) is removed. MOVE TO REPLACE	Left	Right	No Shift
3. NH_4NO_3 (s) is added. MOVE TO REMOVE, BUT (S)	Left	Right	No Shift
4. The pressure is increased by decreasing the volume. GO TO SIDE W/ LESS MOL GAS	Left	Right	No Shift
5. The temperature is increased. RX IS EXO, MOVE ENDO DIRECTION	Left	Right	No Shift

SECTION 2: TRUE/FALSE. (1 point each)

Evaluate the statement in column 1. If it's TRUE, fill in bubble A. If it's FALSE, fill in bubble B.
Evaluate the statement in column 2. If it's TRUE, fill in bubble C. If it's FALSE, fill in bubble D.
If column 2 is the correct explanation for column 1, then bubble E.

- If both columns are TRUE, and column 2 is the correct explanation, bubble ACE.
- If both columns are TRUE, but column 2 is not the correct explanation, bubble AC.
- If column 1 is TRUE and column 2 is FALSE, bubble AD.
- If column 1 is FALSE and column 2 is TRUE, bubble BC.
- If column 1 is FALSE and column 2 is FALSE, bubble BD.

	Column 1		Column 2
ACE	6. A reaction A ⇆ B with K_{eq} = 500 has more products than reactants at equilibrium. K > 1 = PRODUCT FAVORED	BECAUSE	when Q < K_{eq}, the reaction will shift to the right to form more products. GO TOWARDS OPEN MOUTH OF "K"
BC	7. When a system is at equilibrium, the reaction stops NO. EQUILIBRIUM MEANS F/R RATES = NO NET Δ	BECAUSE	at equilibrium, observable, measureable properties of the reaction mixture remain constant. $R_F = R_R$, NO Δ
AC	8. In a reaction X (s) ⇆ Y (g), adding more substance X to an equilibrium mixture will not shift the reaction (S) HAVE CONSTANT [ ] DOES NOT Δ, yes NO SHIFT	BECAUSE	solids and liquids are not included in the equilibrium constant expression (K_{eq}). See ←

SECTION 3: MULTIPLE CHOICE. Select the best answer choice for each question. (1 point each)

9. For the reaction system,
$N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g) + \text{heat}$
the conditions that would shift this equilibrium to the right are
(A) high temperature and high pressure ←, →
(B) high temperature, pressure unimportant ←, X
(C) high temperature and low pressure ←, ←
(D) low temperature and high pressure →, →
(E) low temperature and low pressure →, ←

10. Consider the following equilibrium:
$H_2(g) + I_2(g) \rightleftarrows 2HI(g) \quad \Delta H = -40$ kJ/mol
Which change will shift the equilibrium to the left?
(A) adding $H_2(g)$ →
(B) increasing the temperature ←, EXO
(C) reducing the volume NO Δ
(D) adding a catalyst NO Δ
(E) removing some HI. →

11. Consider the reaction system,
$CoO(s) + H_2(g) \rightleftarrows Co(s) + H_2O(g)$.
The equilibrium constant expression is
(A) $\dfrac{[CoO][H_2]}{[Co][H_2O]}$ SOLIDS NOT IN EXPRESSION
(B) $\dfrac{[Co][H_2O]}{[CoO][H_2]}$
(C) $\dfrac{[Co][H_2O]}{[H_2]}$
(D) $\dfrac{[H_2]}{[H_2O]}$
(E) $\dfrac{[H_2O]}{[H_2]}$

12. Which of the following is/are true at equilibrium?
I. The concentrations of the reactants and products are equal. NO
II. The rates of the forward and reverse reactions are equal. YES
III. The reaction has stopped. NO
(A) I only.
(B) II only.
(C) II and III only.
(D) I and II only.
(E) I, II, and III.

Questions 13-15: Use the following reaction:
$CH_4(g) + 2\,Cl_2(g) \leftrightarrows CCl_4(\ell) + 2\,H_2(g) + \text{heat}$
At 25°C, the value of K_{eq} is 285.

In a particular experiment, some CH_4 and Cl_2 were placed in a container and were allowed to mix until equilibrium was established.

13. The equilibrium expression for this reaction is:
(A) $\dfrac{[CCl_4][H_2]^2}{[CH_4][Cl_2]^2}$ NO "ℓ" IN EXPRESSION
(B) $\dfrac{[H_2]^2}{[CH_4][Cl_2]^2}$
(C) $\dfrac{[H_2]}{[CH_4][Cl_2]}$
(D) $\dfrac{[CH_4][Cl_2]}{[H_2]^2}$
(E) $\dfrac{[2\,H_2]}{[CH_4][2\,Cl_2]}$

14. Which of the following changes to the equilibrium mixture would shift the reaction so that more H_2 (g) would be produced?
I. Add a catalyst NO Δ
II. Add Cl_2 (g) SHIFT →
III. Remove CCl_4 (ℓ) NO Δ
(A) I only.
(B) II only.
(C) I and III only.
(D) II and III only.
(E) I, II, and III.

15. Under which of the following conditions would we have the most CCl_4 (ℓ) when equilibrium is established? (T = temperature, V = volume)
(A) T = 50°C V = 2.0 L WANT LEAST ΔT AND SMALLEST VOL
(B) T = 50°C V = 8.0 L
(C) T = 75°C V = 5.0 L
(D) T = 100°C V = 2.0 L
(E) T = 100°C V = 8.0 L

ΔT SHIFT, ←
SMALL VOL SHIFT, →, less mol/g

Questions 16-17: For the following reaction:

$H_2O\ (\ell) \leftrightarrows H_2O\ (g)$

At 25°C, $K_{eq} = 1.3 \times 10^{-3}$ M.

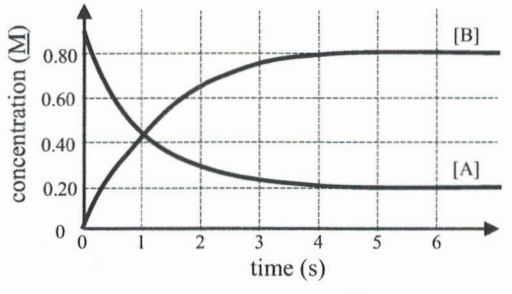
16. If a 50.0 mL sample of $H_2O\ (\ell)$ is placed in a 2.0 L closed container at 25°C. At equilibrium, much of the $H_2O\ (\ell)$ remains, and the concentration of $H_2O\ (g)$ is
    (A) 0 M
    (B) 0.65×10^{-3} M
    (C) 1.3×10^{-3} M
    (D) 2.6×10^{-3} M
    (E) Cannot be determined

$K_{eq} = [H_2O]$

17. If an additional 100 mL of $H_2O\ (\ell)$ is added to the container at the same temperature:
    (A) The pressure of $H_2O\ (g)$ would increase until no $H_2O\ (\ell)$ is left.
    (B) The pressure of $H_2O\ (g)$ would increase until the system reaches equilibrium.
    (C) The pressure of $H_2O\ (g)$ would not change.
    (D) The pressure of $H_2O\ (g)$ would decrease.
    (E) It cannot be determined how the pressure of $H_2O\ (g)$ would change.

$\therefore K_{eq}$ REMAINS CONSTANT $\therefore P_{H_2O}$ NO Δ

Questions 18-20: The graph below shows the concentrations of the reaction A (g) ⇆ 2 B (g) over time.



18. At approximately what time is equilibrium established?
    (A) 0 s
    (B) 1 s
    (C) 2 s
    (D) 3 s
    (E) 4 s

slope D'ing

19. What is the value of the equilibrium constant, K_{eq}, for this reaction A(g) ⇆ 2 B(g)?
    (A) 0.25
    (B) 0.40
    (C) 0.80
    (D) 3.2
    (E) 4.0

$K = \frac{[B]^2}{[A]} = \frac{(.8)^2}{(.2)} = 3.2$

20. In a different experiment for the same reaction, if we started with equal concentrations of A and B, when the system reaches equilibrium,
    (A) [A] > [B]
    (B) [A] ≈ [B]
    (C) [A] < [B]
    (D) [A] = 0
    (E) It cannot be determined from the information given.

$Q < K$, SHIFT (R) FROM GRAPH

IF [ ] > 3.2, THAN SHIFT L

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21. In the reaction: $N_2\ (g) + 3\ H_2\ (g) \leftrightarrows 2\ NH_3\ (g)$ 1.8 mol of N_2, 1.8 mol H_2, and 1.8 mol NH_3 were placed in a 2.0 L vessel. After the reaction mixture was allowed to come to equilibrium, it was found that 0.90 mol H_2 remained in the reaction mixture. How much NH_3 was present at equilibrium?
    (A) 0.90 mol
    (B) 1.2 mol
    (C) 1.8 mol
    (D) 2.4 mol
    (E) 2.7 mol

	N_2	$3H_2$	$\leftrightarrow 2NH_3$
	1.8	1.8	1.8
	$-x$	$-3x$	$+2x$
	1.6	0.9	1.2

$3x = .9$

$x = .3$

(Ans: 2.4)

22. In the reaction
    $2\ NO_2\ (g) \leftrightarrows N_2O_4\ (g)$ $K_{eq} = 2.0$
    A 1.0 L reaction mixture contains 0.20 mol NO_2 and 0.40 mol N_2O_4. The reaction:
    (A) Is at equilibrium. $Q = K$, NO
    (B) Will proceed in the forward direction until it reaches equilibrium. $Q < K$, NO
    (C) Will proceed in the forward direction until the NO_2 runs out. THEN NO Equilibrium
    (D) Will proceed in the reverse direction until it reaches equilibrium. $Q > K$, yes
    (E) Cannot be determined.

Solve For Q:

$Q = \frac{(0.4)}{(.2)^2} = 10 \therefore Q > K$

SECTION 4: FREE RESPONSE. Show all your work to receive full credit.

23. Given the following reaction: $H_2\,(g) + I_2\,(g) \leftrightarrows 2\,HI\,(g)$
At a particular temperature, $K_{eq} = 92.6$.

(a) Write the equilibrium constant expression for the reaction. (2 points)

$$K = \frac{P_{HI}^2}{(P_{H_2})(P_{I_2})}$$

(b) Experiment #1: In a reaction mixture at equilibrium, $[H_2]_{eq} = 0.15$ M and $[HI]_{eq} = 2.2$ M. Find $[I_2]_{eq}$. (4 points)

From a)

$$92.6 = \frac{(2.2)^2}{(.15)(I_2)} \Rightarrow [I_2]_{eq} = 0.35\,M$$

(c) Experiment #2: 0.80 mol H_2, and 0.80 mol I_2 were placed in a 1.0 L container at equilibrium. Find the concentrations of all substances at equilibrium. Use an ICE Box to show your work. (6 points)

	H_2	+ I_2	$\leftrightarrow$	$2\,HI$
I	.8	.8		0
C	$-x$	$-x$		$+2x$
E	$(.8-x)$	$(.8-x)$		$2x$

$$K = \frac{(2x)^2}{(.8-x)(.8-x)} = \text{see last page}$$

(d) Experiment #3: 0.50 mol of H_2, 0.50 mol I_2, and 0.500 mol HI were placed in a 2.0 L container. H_2 and HI are colorless gases, while I_2 is a purple gas.

(i) This reaction: (3 points)
[proceed in the forward direction | is at equilibrium | will proceed in the reverse direction]
because (using math): Solve for Q:

$$Q = \frac{(.5)^2}{(.5)(.5)} = 1 < 92.6 \therefore \text{Shift R (Forward)}$$

(ii) What can we observe when the reaction is at equilibrium? (1 point)

Shifting towards products $\therefore$ Colorless

24. Given the following reaction: heat + N_2O_4 (g) + 2 H_2 (g) ⇆ N_2H_4 (ℓ) + 2 O_2 (g)

(a) The concentrations of the substances in the reaction mixture were found:

$[N_2O_4]_{eq}$ = 0.0247 M $[H_2]_{eq}$ = 0.0495 M $[O_2]_{eq}$ = 0.000545 M

Write the equilibrium constant expression for this reaction and find its value. (4 points)

$K = \frac{[O_2]^2}{[N_2O_4][H_2]^2} = \frac{(5.45E^{-4})^2}{(0.0247)(0.0495)^2} = 0.00491$

(b) At equilibrium, this reaction is: (select one) (1 point)

[reactant-favored | product-favored | about equal reactants and products].

$K < 1 > 0$

(c) In an experiment, 0.500 mol N_2O_4, 0.500 mol H_2, and 0.500 mol O_2 were placed in a 2.0 L container. Determine the direction in which the reaction will proceed, or if the reaction is at equilibrium. Explain briefly. (3 points)

Solve for Q

$Q = \frac{(.5)^2}{(.5)(.5)^2} = 2 > K$ ∴ SHIFT (L)

(d) Determine the how the concentration of each substance will change (↑, –, or ↓) and the direction the reaction will shift (↻, –, or ↺), when each of the changes are applied to a system originally at equilibrium. (4 points)

	$[N_2O_4]$	$[H_2]$	Shift	$[N_2H_4]$	$[O_2]$
Increase temperature	↓	↓	→	–	↑
Increase pressure by decreasing volume	↓	↓	→	–	↑
Add N_2H_4 (ℓ)			No shift		
Remove H_2 (g)	↑	↓	←	↓	↓

Rx →

c)

	$H_{2(g)}$ +	$I_{2(g)}$ ⇌	$2HI_{(g)}$
I	0.80 M	0.80 M	0
C	−x	−x	+2x
E	(0.80−x)	(0.80−x)	2x

$$K = \frac{P_{HI}^2}{P_{H_2} P_{I_2}} \quad \text{since } \Delta n = 0 \rightarrow K = \frac{[HI]^2}{[H_2][I_2]}$$

$$92.6 = \frac{4x^2}{(0.8-x)^2} = \frac{(2x)^2}{(0.8-x)^2}$$

$$\sqrt{K} = 9.62 = \frac{2x}{0.8-x}, \quad 7.69 - 9.62x = 2x$$

$$x = 0.662\ M$$

$[HI] = 0.662 \approx 0.66\ M$

$[H_2] = 0.137 \approx 0.14\ M$

$[I_2] = 0.137 \approx 0.14\ M$

Ans: times 2 --> 1.32 M