

## Exam #3

## Take Home Version

1. When the reversible reaction,  $\text{N}_2 + \text{O}_2 \rightleftharpoons 2 \text{NO}$ , has reached a state of dynamic equilibrium, which statement below is true?

- (a) Both the forward and reverse reactions stop completely and no more NO,  $\text{N}_2$  or  $\text{O}_2$  are produced.
- (b) The rate of the forward reaction equals the rate of the reverse reaction.
- (c) The rate constant of the forward reaction equals the rate constant of the reverse reaction.

2. For the reaction  $2 \text{SO}_2\text{Cl}_2(\text{g}) \rightleftharpoons 2 \text{SO}_2(\text{g}) + \text{Cl}_2(\text{g})$ , the expression for  $K_{eq}$  is

$$(a) K_{eq} = \frac{[\text{SO}_2]^2[\text{Cl}_2]^2}{[\text{SO}_2\text{Cl}_2]^2}$$

$$(d) K_{eq} = \frac{[\text{SO}_2]^2[\text{Cl}_2]}{[\text{SO}_2\text{Cl}_2]}$$

$$(b) K_{eq} = \frac{[\text{SO}_2]^2[\text{Cl}_2]}{[\text{SO}_2\text{Cl}_2]^2}$$

$$(e) K_{eq} = \frac{[\text{SO}_2\text{Cl}_2]^2}{[\text{SO}_2]^2[\text{Cl}_2]}$$

$$(c) K_{eq} = \frac{2[\text{SO}_2]^2[\text{Cl}_2]}{2[\text{SO}_2\text{Cl}_2]^2}$$

3. The equilibrium  $2 \text{SO}_2\text{Cl}_2(\text{g}) \rightleftharpoons 2 \text{SO}_2(\text{g}) + \text{Cl}_2(\text{g})$  has an equilibrium constant of  $K = 22.6$ . What is the value of  $K$  for the equilibrium written as:  $\text{SO}_2(\text{g}) + \frac{1}{2} \text{Cl}_2(\text{g}) \rightleftharpoons \text{SO}_2\text{Cl}_2(\text{g})$ ?

- (a) 22.6      (b) 0.0442      (c) 511      (d) 0.00196      (e) 0.210

4. Consider the system,  $2 \text{CH}_2\text{Cl}_2(\text{g}) \rightleftharpoons \text{CH}_4(\text{g}) + \text{CCl}_4(\text{g})$ , which has an equilibrium constant of  $K = 2.4$ . If a system has:

$$[\text{CH}_2\text{Cl}_2] = 0.22 \text{ M}$$

$$[\text{CH}_4] = 1.64 \text{ M}$$

$$[\text{CCl}_4] = 0.58 \text{ M}$$

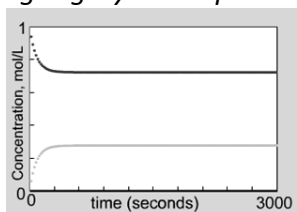
- then, (a) the system is at equilibrium  
 (b) the system is not at equilibrium and will react to form more  $\text{CH}_2\text{Cl}_2$   
 (c) the system is not at equilibrium and will react to form more  $\text{CH}_4$  and  $\text{CCl}_4$

5. The following system is at equilibrium  $\text{CH}_4(\text{g}) + \text{CCl}_4(\text{g}) \rightleftharpoons 2 \text{CH}_2\text{Cl}_2(\text{g})$ .

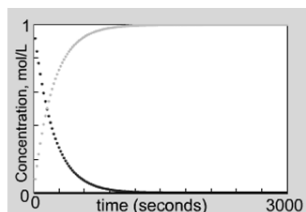
If  $\text{CCl}_4$  is added to the sample, what will then happen to the concentrations of  $\text{CH}_4$  and of  $\text{CH}_2\text{Cl}_2$ ?

- (a) both  $[\text{CH}_4]$  and  $[\text{CH}_2\text{Cl}_2]$  will increase
- (b) both  $[\text{CH}_4]$  and  $[\text{CH}_2\text{Cl}_2]$  will decrease
- (c)  $[\text{CH}_4]$  will decrease and  $[\text{CH}_2\text{Cl}_2]$  will increase
- (d)  $[\text{CH}_4]$  will increase and  $[\text{CH}_2\text{Cl}_2]$  will decrease
- (e)  $[\text{CH}_4]$  will remain constant and  $[\text{CH}_2\text{Cl}_2]$  will increase

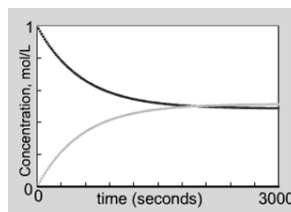
Questions 6-7 use the following concentration-time plots. The black line represents reactants and the light gray line represents products. Answer with the correct letter.



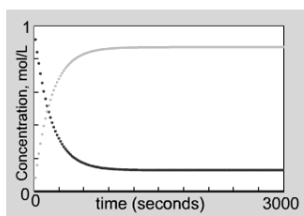
a.



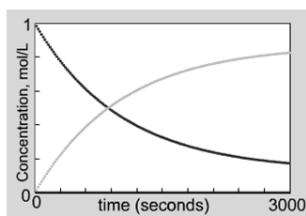
b.



c.



d.



e.

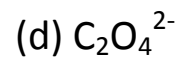
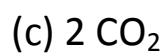
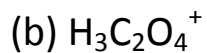
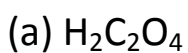
6. Which reaction goes to completion?

Choose the letter

7. Which reaction has the smallest equilibrium constant?

Choose the letter

8. What is the conjugate base of  $\text{HC}_2\text{O}_4^-$ ?



9. What is the pH of a 0.000483 M solution of NaOH?

(a)  $4.83 \times 10^{-4}$

(b)  $2.07 \times 10^{-11}$

(c) 3.31

(d) 10.68

(e) 7.00

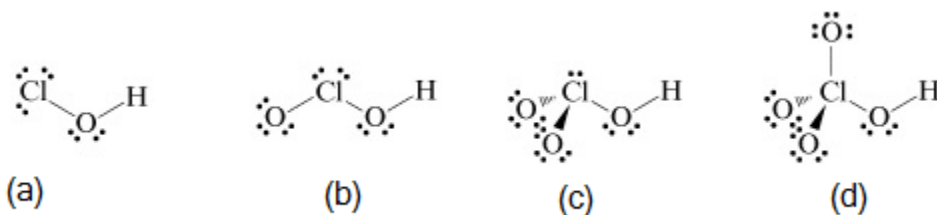
10. What are  $[\text{H}_3\text{O}^+]$  and  $[\text{OH}^-]$  for a solution that has a pH of 9.0?

- (a)  $[\text{H}_3\text{O}^+] = 9 \text{ M}$  and  $[\text{OH}^-] = 5 \text{ M}$
- (b)  $[\text{H}_3\text{O}^+] = 5 \text{ M}$  and  $[\text{OH}^-] = 9 \text{ M}$
- (c)  $[\text{H}_3\text{O}^+] = 1 \times 10^9 \text{ M}$  and  $[\text{OH}^-] = 1 \times 10^5 \text{ M}$
- (d)  $[\text{H}_3\text{O}^+] = 1 \times 10^{-5} \text{ M}$  and  $[\text{OH}^-] = 1 \times 10^{-9} \text{ M}$
- (e)  $[\text{H}_3\text{O}^+] = 1 \times 10^{-9} \text{ M}$  and  $[\text{OH}^-] = 1 \times 10^{-5} \text{ M}$

11. Which of the following are the pH ranges expected for solutions of  $\text{NH}_4\text{NO}_3$  and  $\text{KCN}$ ?

- a)  $\text{NH}_4\text{NO}_3$  is acidic and  $\text{KCN}$  is basic
- b)  $\text{NH}_4\text{NO}_3$  is acidic and  $\text{KCN}$  is neutral
- c)  $\text{NH}_4\text{NO}_3$  is basic and  $\text{KCN}$  is basic
- d)  $\text{NH}_4\text{NO}_3$  is neutral and  $\text{KCN}$  is acidic

12. Which of the following acids has the largest  $K_a$  value?



13. Consult the table of  $K_a$  values provided. Is it possible for a solution of hydrofluoric acid to have a higher pH than a solution of formic acid? That's all the information you are given- don't ask for more.

- (a) yes                      (b) no                      (c) it is impossible to answer

14. A chemical system has an equilibrium constant of  $1.4 \times 10^{-6}$ . This means:

- (a)  $\Delta G^\circ$  is positive and the system is reactant-favored
- (b)  $\Delta G^\circ$  is negative and the system is product-favored
- (c)  $\Delta G$  is positive and the system is not spontaneous
- (d)  $\Delta G$  is negative and the system is spontaneous

## Exam #3B: ANSWER SHEET

Name: \_\_\_\_\_

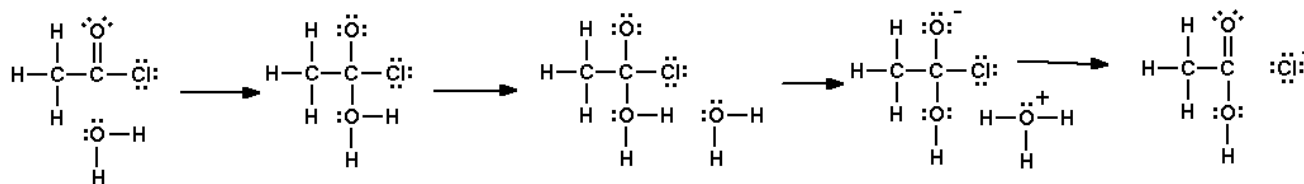
- |    |   |   |   |   |   |     |   |   |   |   |   |
|----|---|---|---|---|---|-----|---|---|---|---|---|
| 1. | a | b | c | d | e | 8.  | a | b | c | d | e |
| 2. | a | b | c | d | e | 9.  | a | b | c | d | e |
| 3. | a | b | c | d | e | 10. | a | b | c | d | e |
| 4. | a | b | c | d | e | 11. | a | b | c | d | e |
| 5. | a | b | c | d | e | 12. | a | b | c | d | e |
| 6. | a | b | c | d | e | 13. | a | b | c | d | e |
| 7. | a | b | c | d | e | 14. | a | b | c | d | e |

15. Write the net-ionic equation for the acid-base reaction occurring between HClO and KOH.

16. Consider the following set of reaction steps. Add the following labels to the species they represent. Point to the species and add the label. You label four things in total. If something is both Lewis and Bronsted, label it Bronsted. For example, find something that is acting as a Lewis Acid and draw an arrow to it labeled with "LA."

BA = Bronsted Acid  
BB = Bronsted Base

LA = Lewis Acid  
LB = Lewis Base



17. For each of the following, circle the one that will have the higher pH (or circle they are the same):

- a. 0.1 M CH<sub>3</sub>CO<sub>2</sub>H    or    0.1 M NaCH<sub>3</sub>CO<sub>2</sub>    or    same
- b. 0.1 M HCl    or    0.1 NaOH    or    same
- c. 0.1 M HCl    or    0.1 M HNO<sub>3</sub>    or    same

18. A student ran the following reaction in the laboratory at 450 K:  $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$   
When she introduced 0.789 moles of  $\text{PCl}_5(\text{g})$  into a 1.00 liter container, she found the equilibrium concentration of  $\text{Cl}_2(\text{g})$  to be 0.0312 M. Calculate the equilibrium constant,  $K_c$ .

$K_c =$  \_\_\_\_\_

19. Butene isomerizes to form cyclobutane.



If a sample of 1.00 M butene is placed in a flask and allowed to react, what will [cyclobutane] be once equilibrium is established?

20. What is the pH of a 0.0030 M solution of HF?

pH = \_\_\_\_\_

21. A 0.100 M solution of a weak acid, HA, has pH = 3.88 at 25 °C and pH = 3.10 at 55 °C. What are  $\Delta H^\circ$  and  $\Delta S^\circ$  for the weak acid ionization reaction?

## Useful Information

$$\text{pH} = -\log[\text{H}_3\text{O}^+]$$

$$\text{pOH} = -\log[\text{OH}^-]$$

$$K_w = 1.0 \times 10^{-14} \text{ at } 25^\circ\text{C}$$

$$[\text{H}_3\text{O}^+] = 10^{-\text{pH}}$$

$$[\text{OH}^-] = 10^{-\text{pOH}}$$

$$\Delta G^\circ = -RT \ln K$$

$$\Delta G = \Delta G^\circ + RT \ln Q$$

K <sub>a</sub> and K <sub>b</sub> Values					
Name of Acid	Acid	K <sub>a</sub>	Name of Base	Base	K <sub>b</sub>
Hydrogen sulfate ion	HSO <sub>4</sub> <sup>-</sup>	1.2 × 10 <sup>-2</sup>	sulfate ion	SO <sub>4</sub> <sup>2-</sup>	8.3 × 10 <sup>-13</sup>
Phosphoric acid	H <sub>3</sub> PO <sub>4</sub>	7.5 × 10 <sup>-3</sup>	dihydrogen phosphate ion	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	1.3 × 10 <sup>-12</sup>
Hexaaquairon(III) ion	Fe(H <sub>2</sub> O) <sub>6</sub> <sup>3+</sup>	6.3 × 10 <sup>-3</sup>	pentaquahydroxoiron(III) ion	Fe(H <sub>2</sub> O) <sub>5</sub> OH <sup>2+</sup>	1.6 × 10 <sup>-12</sup>
Hydrofluoric acid	HF	7.4 × 10 <sup>-4</sup>	fluoride ion	F <sup>-</sup>	1.4 × 10 <sup>-11</sup>
Formic acid	HCO <sub>2</sub> H	1.8 × 10 <sup>-4</sup>	formate ion	HCO <sub>2</sub> <sup>-</sup>	5.6 × 10 <sup>-11</sup>
Benzoic acid	C <sub>6</sub> H <sub>5</sub> CO <sub>2</sub> H	6.3 × 10 <sup>-5</sup>	benzoate ion	C <sub>6</sub> H <sub>5</sub> CO <sub>2</sub> <sup>-</sup>	1.6 × 10 <sup>-10</sup>
Acetic acid	CH <sub>3</sub> CO <sub>2</sub> H	1.8 × 10 <sup>-5</sup>	acetate ion	CH <sub>3</sub> CO <sub>2</sub> <sup>-</sup>	5.6 × 10 <sup>-10</sup>
Hexaaquaaluminum ion	Al(H <sub>2</sub> O) <sub>6</sub> <sup>3+</sup>	7.9 × 10 <sup>-6</sup>	pentaquahydroxoaluminum ion	Al(H <sub>2</sub> O) <sub>5</sub> OH <sup>2+</sup>	1.3 × 10 <sup>-9</sup>
Carbonic acid	H <sub>2</sub> CO <sub>3</sub>	4.2 × 10 <sup>-7</sup>	hydrogen carbonate ion	HCO <sub>3</sub> <sup>-</sup>	2.4 × 10 <sup>-8</sup>
Hydrogen sulfide	H <sub>2</sub> S	1 × 10 <sup>-7</sup>	hydrogen sulfide ion	HS <sup>-</sup>	1 × 10 <sup>-7</sup>
Dihydrogen phosphate ion	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	6.2 × 10 <sup>-8</sup>	hydrogen phosphate ion	HPO <sub>4</sub> <sup>2-</sup>	1.6 × 10 <sup>-7</sup>
Hypochlorous acid	HClO	3.5 × 10 <sup>-8</sup>	hypochlorite ion	ClO <sup>-</sup>	2.9 × 10 <sup>-7</sup>
Ammonium ion	NH <sub>4</sub> <sup>+</sup>	5.6 × 10 <sup>-10</sup>	ammonia	NH <sub>3</sub>	1.8 × 10 <sup>-5</sup>
Hydrocyanic acid	HCN	4.0 × 10 <sup>-10</sup>	cyanide ion	CN <sup>-</sup>	2.5 × 10 <sup>-5</sup>
Hexaaquairon(II) ion	Fe(H <sub>2</sub> O) <sub>6</sub> <sup>2+</sup>	3.2 × 10 <sup>-10</sup>	pentaquahydroxoiron(II) ion	Fe(H <sub>2</sub> O) <sub>5</sub> OH <sup>+</sup>	3.1 × 10 <sup>-5</sup>
Hydrogen carbonate ion	HCO <sub>3</sub> <sup>-</sup>	4.8 × 10 <sup>-11</sup>	carbonate ion	CO <sub>3</sub> <sup>2-</sup>	2.1 × 10 <sup>-4</sup>
Hydrogen phosphate ion	HPO <sub>4</sub> <sup>2-</sup>	3.6 × 10 <sup>-13</sup>	phosphate ion	PO <sub>4</sub> <sup>3-</sup>	2.8 × 10 <sup>-2</sup>

1	IA																										18	VIIIA										
1	1	1.0079																										2	4.0026									
	<b>H</b>																											<b>He</b>										
	HYDROGEN																											HELIUM										
2	3	6.941	4	9.0122																							5	10.811	6	12.011	7	14.007	8	15.999	9	18.998	10	20.180
	<b>Li</b>	<b>Be</b>																	<b>B</b>	<b>C</b>	<b>N</b>	<b>O</b>	<b>F</b>	<b>Ne</b>														
	LITHIUM	BERYLLIUM																	BORON	CARBON	NITROGEN	OXYGEN	FLUORINE	NEON														
3	11	22.990	12	24.305																							13	26.982	14	28.086	15	30.974	16	32.065	17	35.453	18	39.948
	<b>Na</b>	<b>Mg</b>																	<b>Al</b>	<b>Si</b>	<b>P</b>	<b>S</b>	<b>Cl</b>	<b>Ar</b>														
	SODIUM	MAGNESIUM																	ALUMINUM	SILICON	PHOSPHORUS	SULPHUR	CHLORINE	ARGON														
4	19	39.098	20	40.078	21	44.956	22	47.867	23	50.942	24	51.996	25	54.938	26	55.845	27	58.933	28	58.693	29	63.546	30	65.39	31	69.723	32	72.64	33	74.922	34	78.96	35	79.904	36	83.80		
	<b>K</b>	<b>Ca</b>	<b>Sc</b>	<b>Ti</b>	<b>V</b>	<b>Cr</b>	<b>Mn</b>	<b>Fe</b>	<b>Co</b>	<b>Ni</b>	<b>Cu</b>	<b>Zn</b>	<b>Ga</b>	<b>Ge</b>	<b>As</b>	<b>Se</b>	<b>Br</b>	<b>Kr</b>																				
	POTASSIUM	CALCIUM	SCANDIUM	TITANIUM	VANADIUM	CHROMIUM	MANGANESE	IRON	COBALT	NICKEL	COPPER	ZINC	GALLIUM	GERMANIUM	ARSENIC	SELENIUM	BROMINE	KRYPTON																				
5	37	85.468	38	87.62	39	88.906	40	91.224	41	92.906	42	95.94	43	(98)	44	101.07	45	102.91	46	106.42	47	107.87	48	112.41	49	114.82	50	118.71	51	121.76	52	127.60	53	126.90	54	131.29		
	<b>Rb</b>	<b>Sr</b>	<b>Y</b>	<b>Zr</b>	<b>Nb</b>	<b>Mo</b>	<b>Tc</b>	<b>Ru</b>	<b>Rh</b>	<b>Pd</b>	<b>Ag</b>	<b>Cd</b>	<b>In</b>	<b>Sn</b>	<b>Sb</b>	<b>Te</b>	<b>I</b>	<b>Xe</b>																				
	RUBIDIUM	STRONTIUM	YTRIUM	ZIRCONIUM	NIوبيUM	MOLYBDENUM	TECHNETIUM	RUTHENIUM	RHODIUM	PALLADIUM	SILVER	CADMIUM	INDIUM	TIN	ANTIMONY	TELLURIUM	IODINE	XENON																				
6	55	132.91	56	137.33	57-71	72	178.49	73	180.95	74	183.84	75	186.21	76	190.23	77	192.22	78	195.08	79	196.97	80	200.59	81	204.38	82	207.2	83	208.98	84	(209)	85	(210)	86	(222)			
	<b>Cs</b>	<b>Ba</b>	La-Lu Lanthanide	<b>Hf</b>	<b>Ta</b>	<b>W</b>	<b>Re</b>	<b>Os</b>	<b>Ir</b>	<b>Pt</b>	<b>Au</b>	<b>Hg</b>	<b>Tl</b>	<b>Pb</b>	<b>Bi</b>	<b>Po</b>	<b>At</b>	<b>Rn</b>																				
	CAESIUM	BARIUM		HAFNIUM	TANTALUM	TUNGSTEN	RHENIUM	OSMIUM	IRIDIUM	PLATINUM	GOLD	MERCURY	THALLIUM	LEAD	BISMUTH	POLONIUM	ASTATINE	RADON																				