KEY

Equilibrium, Acids and Bases Review

Use the following information to answer the first question.

Methane gas can be produced in a laboratory by reacting carbon disulfide, $CS_2(g)$, and hydrogen gas, as represented by the equation below.

$$CS_2(g) + 4\,H_2(g) \rightleftharpoons CH_4(g) + 2\,H_2S(g)$$

The initial concentrations that are placed into an empty flask at a temperature of 90.0 °C are 0.175 mol/L $CS_2(g)$ and 0.310 mol/L $H_2(g)$. When equilibrium is established, 0.125 mol/L $CS_2(g)$ is present.

Written Response—10% **(5 marks for content, 1 mark for overall communication)**

1. **a.** **Determine** the concentration of hydrogen gas present in the flask at equilibrium. **(3 marks)**

	CS_2	+	$4H_2$	⇌	CH_4	+	$2H_2S$
I	0.175		0.310		0		0
C	−0.05		−0.20		+0.05		+0.10
E	0.125		0.110 mol/L		0.05		0.10

b. Write the equilibrium law expression for the reaction, and **determine** the equilibrium constant for the reaction at 90.0 °C. **(2 marks)**

$$K_c = \frac{[CH_4][H_2S]^2}{[CS_2][H_2]^4} = \frac{(0.05)(0.10)^2}{(0.125)(0.110)^4} = 27.3$$

Use the following information to answer the next question.

Dinitrogen tetraoxide was used as one of the rocket fuels on the lunar landers of the Apollo missions. In the gaseous phase, it decomposes according to the following equation.

$$N_2O_4(g) \rightleftharpoons 2\,NO_2(g) \qquad \Delta H° = +55.3\ kJ$$

A technician placed a sample of $N_2O_4(g)$ in a 2.00 L flask and allowed the system to reach equilibrium. At 25 °C, the K_c was 5.40×10^{-3}, and the concentration of $N_2O_4(g)$ at equilibrium was 3.00×10^{-1} mol/L.

Written Response—10% (5 marks for content, 1 mark for overall communication)

11. **a.** **Determine** the amount, in moles, of $NO_2(g)$ present in the 2.00 L flask at equilibrium. **(3 marks)**

$K_c = \dfrac{[NO_2]^2}{[N_2O_4]}$

$0.00540 = \dfrac{[NO_2]^2}{0.300}$

$[NO_2] = 0.0402\ldots\ mol/L$

$n = cv = (0.0402\ldots\ mol/L)(2.00L)$

$= 0.0805\ mol$

b. **Identify** whether the value of K_c will increase, decrease, or remain the same when heat is added to the system. Support your answer with an explanation. **(2 marks)**

increase b/c more products will be produced

$K_c = \dfrac{prod.}{react.}$

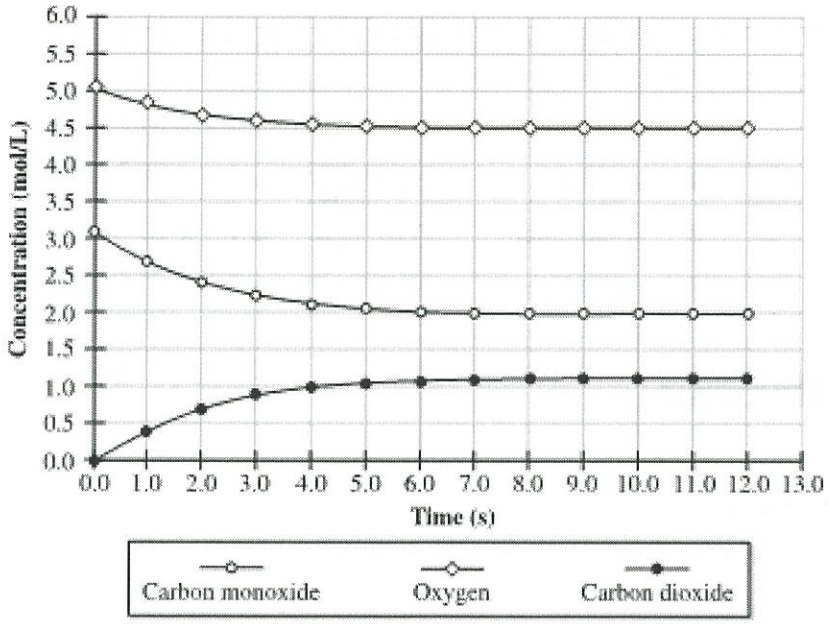
Use the following information to answer the next question.

Carbon monoxide gas and oxygen gas react to form carbon dioxide gas as represented by the equilibrium equation below.

$$2\,CO(g) + O_2(g) \rightleftharpoons 2\,CO_2(g)$$

A technician added carbon monoxide gas and oxygen gas to an empty flask. The technician then recorded the concentrations of each gas present in the flask until the reaction reached equilibrium at 500 K, as shown in the graph below.

Concentration of Gases at Equilibrium



Written Response—10% (5 marks for content, 1 mark for overall communication)

14. **a.** Write the equilibrium law expression, and **calculate** the value for the equilibrium constant at 500 K. **(3 marks)**

$K_c = \dfrac{[CO_2]^2}{[CO]^2[O_2]} = \dfrac{(1.1)^2}{(2.0)^2(4.5)} = 0.067$

b. Indicate whether the products or reactants are favoured in this reaction and **explain** your answer. **(2 marks)**

reactants b/c $K_c < 1$

34. A chemical equilibrium system is always characterized by

A. the presence of equal amounts of reactants and products

B. the completion of a chemical reaction when changes cease to occur

C. equal amounts of reactants and products entering and being removed from the system

D. the conversion of reactants to products occurring at the same rate as the conversion of products to reactants

Use the following information to answer the next question.

1	lime juice	$[OH^-_{(aq)}]$	$= 7.7 \times 10^{-13}$ mol/L
2	salmon	$[H_3O^+_{(aq)}]$	$= 6.3 \times 10^{-7}$ mol/L
3	apple cider	$[OH^-_{(aq)}]$	$= 1.3 \times 10^{-11}$ mol/L
4	egg white	$[H_3O^+_{(aq)}]$	$= 3.0 \times 10^{-8}$ mol/L

Numerical Response

10. When these foods are listed from most acidic to least acidic, the order is 1324.
(Record all four digits on the answer sheet.)

35. A solution of hydrocyanic acid has a pH of 4.80. The concentration of the $HCN_{(aq)}$ solution is

A. 0.16 mol/L
B. 0.25 mol/L
C. 0.41 mol/L
D. 0.65 mol/L

$[H_3O^+] = 10^{-4.80}$
$= 1.584... \times 10^{-5}$ mol/L

$K_a = \frac{[H_3O^+][CN^-]}{[HCN]}$ $\quad 6.2 \times 10^{-10} = \frac{(1.584... \times 10^{-5})^2}{[HCN]}$

Use the following information to answer the next question.

A student sampled four different acids, each at 0.10 mol/L, and she recorded these observations.

	Volume (mL)	pH	Conductivity
Acid I	50.2	4.50	poor
Acid II	40.5	3.25	poor
Acid III	20.7	1.50	good
Acid IV	15.0	5.50	poor

36. The acid that would be expected to have the lowest K_a value would be

weakest acid
highest pH

A. Acid I
B. Acid II
C. Acid III
D. Acid IV

37. The Brønsted-Lowry theory of acids and bases is similar to redox theory in that

A. most acids can act as oxidizing agents
B. an oxidizing agent donates electrons and acts like an acid
C. the base in an acid-base reaction acts like a reducing agent
D. there is a transfer of a charged particle in both

Use the following information to answer the next question.

Manufacturers used to add alum during the production of paper. The aluminum ion in alum is hydrated, and the following equilibrium established:

$$Al(H_2O)_6^{3+}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons Al(OH)(H_2O)_5^{2+}{}_{(aq)} + H_3O^+{}_{(aq)} \quad K_a = 1.4 \times 10^{-5}$$

Numerical Response

11. If $[Al(H_2O)_6^{3+}{}_{(aq)}] = 0.150$ mol/L, the pH of the system at equilibrium is 2.84.

(Record your answer to three digits on the answer sheet.)

Use the following information to answer the next question.

Kelly tested portions of a solution with three indicators to determine the approximate pH.

Indicator	Colour
bromocresol green	blue
indigo carmine	blue
thymolphthalein	blue

38. The approximate pH of the solution is

A. 5.0
B. 9.0
C. 10.8
D. 11.6

Numerical Response

12. Four test tubes each contain 10.0 mL of 0.10 mol/L $HCl_{(aq)}$. Each test tube also contains a different indicator as listed below:

Test tube	Indicator
1	indigo carmine
2	thymol blue
3	methyl red
4	methyl orange

One drop of 0.10 mol/L $NaOH_{(aq)}$ is added to each test tube, and the colour is noted. A second drop of $NaOH_{(aq)}$ is added to each test tube, and colour is again observed. The same procedure is repeated until all solutions are yellow. In what order did the solutions in the test tubes turn yellow? 2431
(Record all four digits on the answer sheet.)

40. Which species is **not** amphiprotic?

A. $H_2O_{(l)}$
B. $HS^-_{(aq)}$
C. $NH_4^+{}_{(aq)}$
D. $H_2BO_3^-{}_{(aq)}$

41. Which acid is **not** polyprotic?

A. $HOOCCOOH_{(aq)}$

B. $HCOOH_{(aq)}$

C. $H_2SO_{3(aq)}$

D. $H_3PO_{4(aq)}$

42. When a small volume of a strong acid is added to a buffer, the pH of the solution should

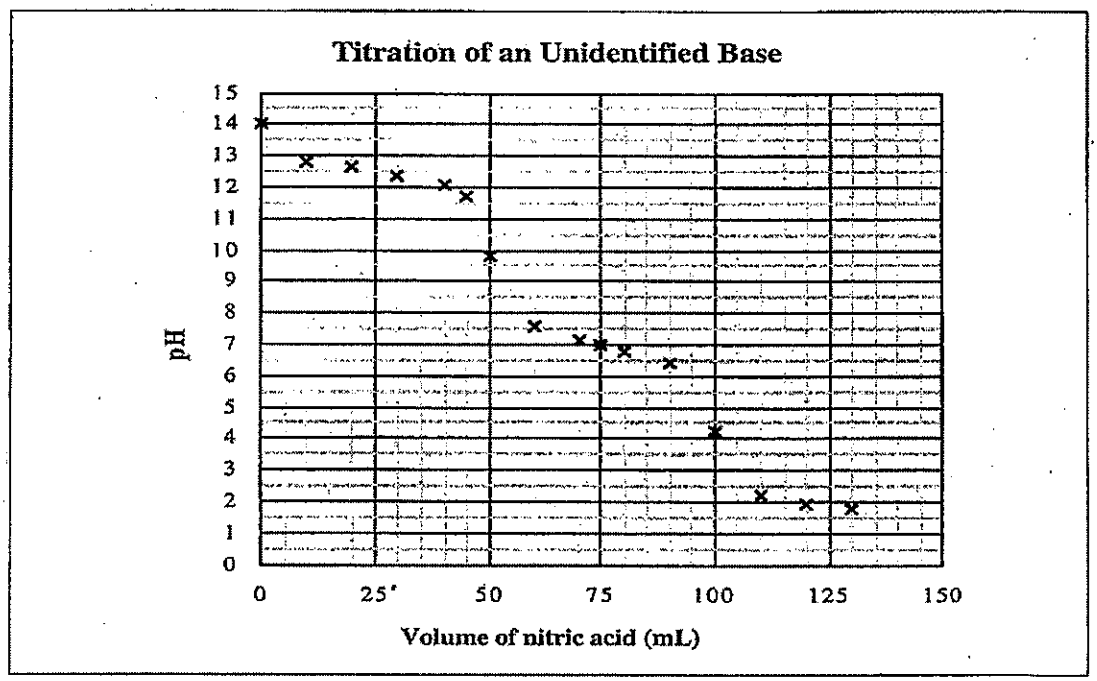
A. increase

B. decrease

C. remain constant

D. increase first and then decrease

Use the following information to answer the next question.



44. Which indicators can be used to accurately estimate the first and second equivalence-points?

A. Thymolphthalein – methyl orange

B. Thymolphthalein – thymol blue

C. Alizarin yellow – thymol blue

D. All of the above