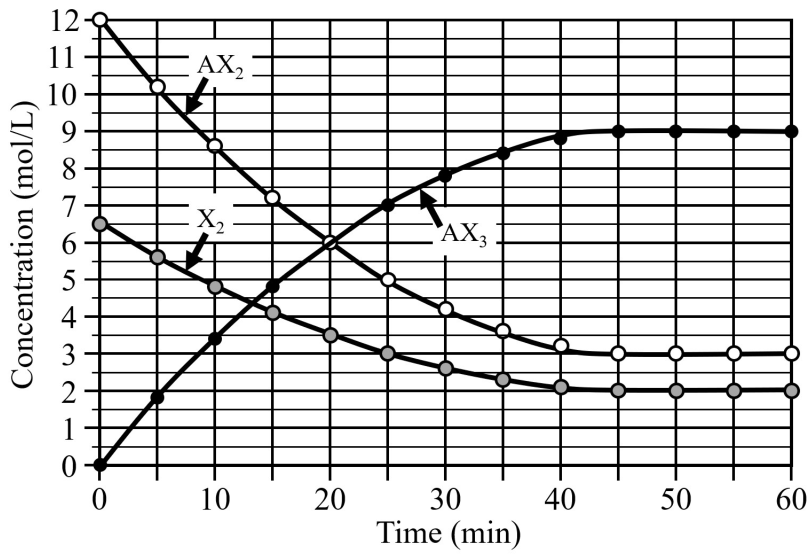
Unit 7 Summative Assessment Practice

Show your work for each question in the space provided. Examples and equations may be included in your responses where appropriate. For calculations, clearly show the method used and the steps involved in arriving at your answers. You must show your work to receive credit for your answer. Pay attention to significant figures.

$$2\ AX_2(g) + X_2(g) \rightleftarrows 2\ AX_3(g)$$

1. Samples of $AX_2(g)$ and $X_2(g)$ are added to a previously evacuated rigid reaction vessel. A reaction occurs at 200°C according to the equation shown above. The concentration of each substance is monitored over time, and the data are shown on the graph below.



(a) Write the expression for the equilibrium constant (K_c) for the reaction.

(b) On the graph above, draw a vertical line indicating the point in time during the reaction at which the system reached equilibrium. Give a specific justification for the line that you drew in terms of the appearance of the data in the graph.

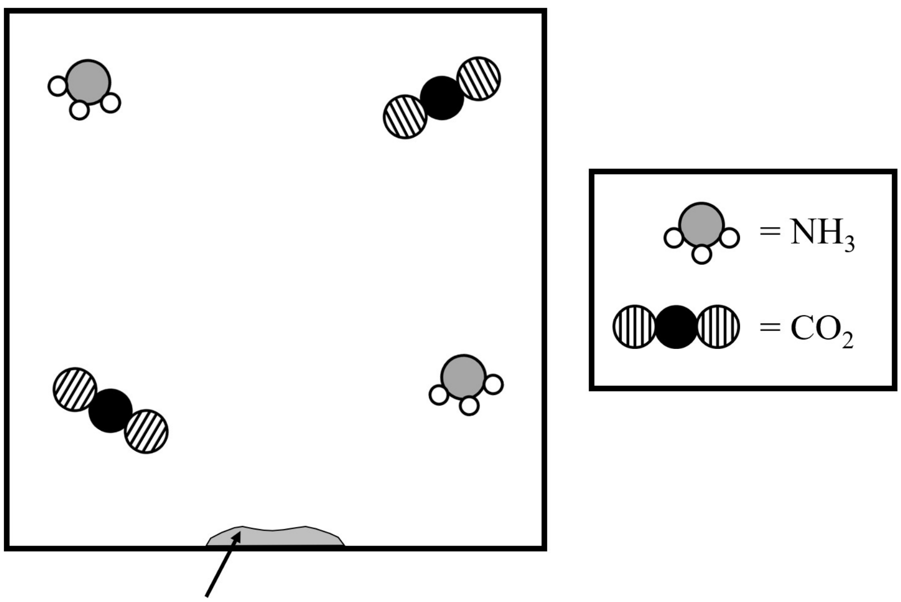
(c) Based on the information in the graph, calculate the value of K_c for this reaction at 200°C.

$$NH_4CO_2NH_2(s) \rightleftarrows 2\,NH_3(g) + CO_2(g)$$

2. A sample of solid $NH_4CO_2NH_2$ was placed in a previously evacuated rigid 5.00 L reaction vessel at 350 K. A chemical reaction occurred, producing $NH_3(g)$ and $CO_2(g)$ according to the equation shown above. As the reaction proceeded, the total pressure in the container was monitored. Solid $NH_4CO_2NH_2$ remained in the reaction vessel at all times.

(a) Write the expression for the equilibrium constant (K_p) for the reaction.

(b) The diagram below is incomplete. Complete the particle diagram so that it accurately displays a representative sample of the gas mixture in the reaction vessel at equilibrium.



Solid $NH_4CO_2NH_2$

When the system reached equilibrium at 350 K, the total pressure of the gas mixture in the reaction vessel was 0.324 atm. Assume that the volume of the solid is negligible.

(c) Determine the partial pressure of $NH_3(g)$ and $CO_2(g)$ in the reaction vessel at equilibrium.

P_{NH_3} = _______________ atm $\qquad$ P_{CO_2} = _______________ atm

(d) Calculate the value of K_p for the reaction shown above at 350 K.

2. (continued)

(e) Calculate the number of moles of $CO_2(g)$ present in the reaction vessel at equilibrium.

(f) After the system had reached equilibrium at 350 K, a 5.0 g sample of $NH_4CO_2NH_2(s)$ is added to the reaction vessel. Assume that the volume of $NH_4CO_2NH_2(s)$ is negligible and that the temperature of the system is held constant at 350 K. After the addition of $NH_4CO_2NH_2(s)$ to the reaction vessel, should the partial pressure of $CO_2(g)$ decrease, increase, or remain the same? Justify your answer.

$$2\ NO(g) + O_2(g) \rightleftarrows 2\ NO_2(g) \qquad K_p = 2.4 \times 10^{12} \text{ at } 300\text{ K}$$

3. Samples of $NO(g)$ and $O_2(g)$ are introduced into a previously evacuated rigid container at 300 K. The partial pressures of the gases in the container before any reaction occurs are the following.

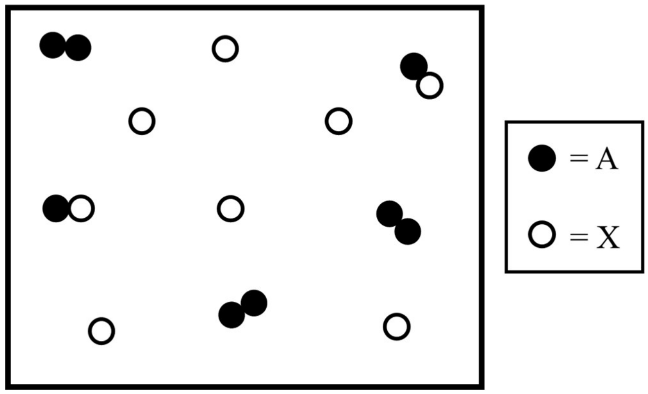
$$P_{NO} = 5.00 \text{ atm} \qquad P_{O_2} = 3.00 \text{ atm}$$

The temperature is held constant at 300 K as the reaction represented by the equation shown above reaches equilibrium. Considering the value of K_p, calculate the total pressure in the reaction vessel at equilibrium.

$$A_2(g) + 2\,X(g) \rightleftarrows 2\,AX(g) \qquad K_c = 9.0 \text{ at } 500\text{ K}$$

4. Substance $A_2(g)$ reacts with substance $X(g)$ according to the equation shown above. The value of K_c for this reaction is 9.0 at 500 K.

   The particulate diagram below shows a representative sample of the reaction mixture at a certain point during the reaction. Each particle in the diagram represents one mole of the substance in a 1.00 L container at 500 K.



   The system represented by the particulate diagram above is not at equilibrium As equilibrium is established, do you predict that the number of moles of $A_2(g)$ should decrease, increase, or remain the same? Justify your answer by comparing the value of the reaction quotient (Q_c) with the value of the equilibrium constant (K_c).

	Equation	K_p at 300 K
#1	$X(g) + Y(g) \rightleftarrows XY(g)$	0.42
#2	$A(g) + 3\,X(g) \rightleftarrows AX_3(g)$	25
#3	$AX_3(g) + 3\,Y(g) \rightleftarrows A(g) + 3\,XY(g)$	?

5. Three chemical equations are listed in the table above. In the space below, show how equations #1 and #2 can be combined in a certain way in order to produce equation #3. Calculate the equilibrium constant (K_p) for equation #3.

$$SO_2(g) + NO_2(g) \rightleftarrows SO_3(g) + NO(g) \qquad K_c = 0.70 \text{ at } 450°C$$

6. Sulfur dioxide, $SO_2(g)$, reacts with nitrogen dioxide, $NO_2(g)$, according to the equation shown above. The value of K_c for this reaction is 0.70 at 450°C. Samples of each gas involved in the reaction are introduced into a previously evacuated rigid reaction vessel at 450°C. The concentrations of the gases in the container before any reaction occurs are the following.

$[SO_2] = 3.00\ M \qquad [NO_2] = 3.00\ M \qquad [SO_3] = 4.00\ M \qquad [NO] = 4.00\ M$

(a) Calculate the value of the reaction quotient (Q_c) for the system at this point in time.

(b) As equilibrium is established for this reaction at 450°C, do you predict that the concentration of $SO_2(g)$ should decrease, increase, or remain the same? Justify your answer by comparing the value of the reaction quotient (Q_c) with the value of the equilibrium constant (K_c).

(c) Calculate the values for the concentration of all four substances in the reaction vessel when equilibrium is achieved at 450°C.

$[SO_2]$ = _________ M $[NO_2]$ = _________ M $[SO_3]$ = _________ M $[NO]$ = _________ M

6. (continued)

$$SO_2(g) + NO_2(g) \rightleftarrows SO_3(g) + NO(g) \qquad K_c = 0.70 \text{ at } 450°C$$

(d) Another experiment is run at 450°C in which the reaction system represented by the equation above is allowed to achieve equilibrium. The concentrations of the gases in the container at equilibrium are the following.

$[SO_2] = 1.48\ M$ $\qquad$ $[NO_2] = 1.48\ M$ $\qquad$ $[SO_3] = 1.24\ M$ $\qquad$ $[NO] = 1.24\ M$

The volume of the container is rapidly doubled from 2.00 L to 4.00 L while the temperature is held constant at 450°C. After this change in the container volume occurs, do you predict that the number of moles of $SO_2(g)$ should increase, decrease, or remain the same? Justify your answer.

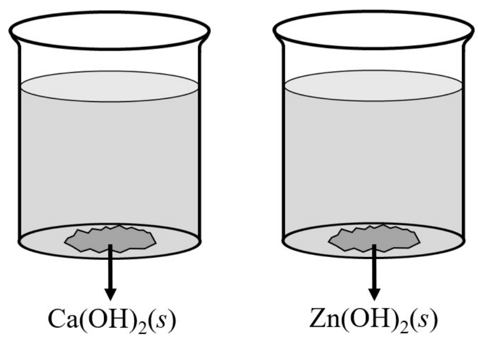
K_c at two different temperatures for the following reaction $SO_2(g) + NO_2(g) \rightleftarrows SO_3(g) + NO(g)$	
Temperature	K_c
250°C	10.0
450°C	0.70

(e) Based on the information in the table above, is the forward reaction (from left to right) endothermic or exothermic? Justify your answer in terms of Le Châtelier's principle.

Compound	calcium hydroxide $Ca(OH)_2$	zinc hydroxide $Zn(OH)_2$
K_{sp} at 25°C	5.0×10^{-6}	3.0×10^{-17}

7. The solubility-product constant (K_{sp}) for two different metal hydroxides are listed in the table above. Answer the following questions related to these substances.

(a) A student added an excess amount of $KOH(aq)$ to a solution of $Zn(NO_3)_2(aq)$, resulting in the formation of a precipitate. Write the net ionic equation for the reaction that occurred in this experiment.



Saturated solutions of $Ca(OH)_2$ and $Zn(OH)_2$ were prepared at 25°C in two separate beakers by adding excess amounts of the solid to distilled water and stirring the mixture thoroughly. A small amount of undissolved solid remained at the bottom of each beaker, as shown in the diagram above.

(b) Without doing any calculations, identify the solution that has the larger value for $[OH^-]$. Justify your answer.

(c) Calculate the value of $[OH^-]$ (in mol/L) in the saturated solution that you selected in part (b).

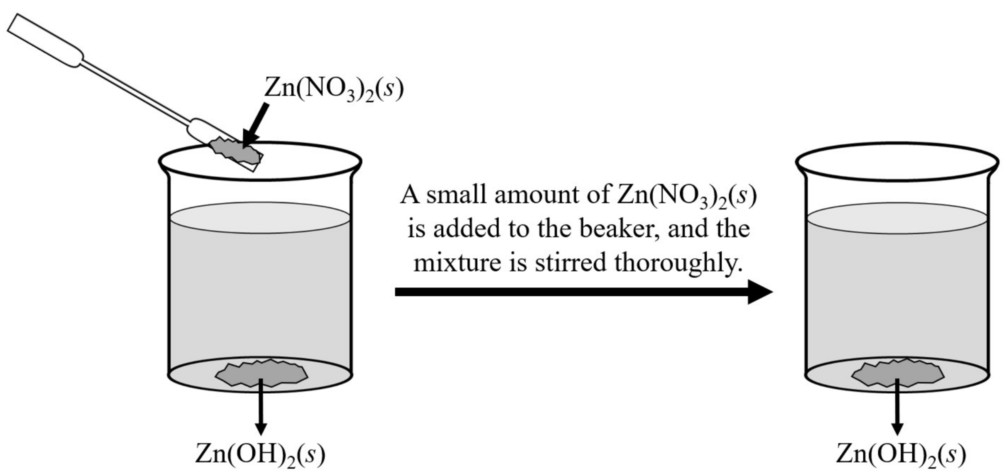
7. (continued)

(d) In a separate experiment, a 125.0 mL sample of 7.5×10^{-6} M $Zn(NO_3)_2(aq)$ is added to a 175.0 mL sample of 8.2×10^{-6} M $NaOH(aq)$. The mixture is stirred to ensure that it is thoroughly mixed.

(i) The volume of the mixture formed in this experiment is 300.0 mL. Calculate the <u>initial</u> concentrations of $Zn^{2+}(aq)$ and $OH^{-}(aq)$ in the mixture at the moment that the two solutions are combined, but <u>before</u> any chemical reaction occurs.

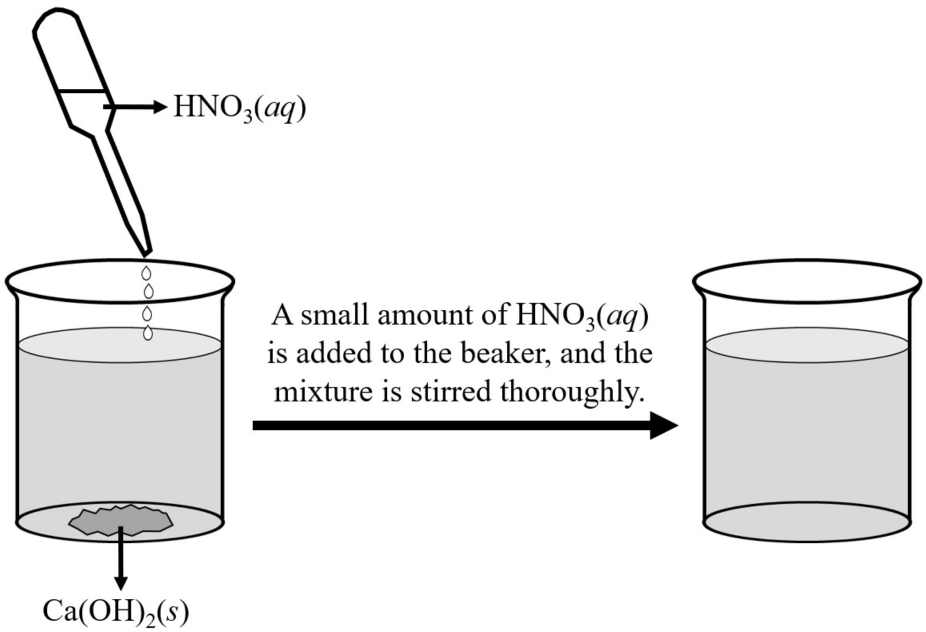
$[Zn^{2+}]$ = ____________ M $\qquad$ $[OH^{-}]$ = ____________ M

(ii) Do you predict that a precipitate of $Zn(OH)_2(s)$ will be formed in this experiment? Justify your answer by comparing the value of the reaction quotient (Q_{sp}) with the value of the solubility-product constant (K_{sp}).



(e) In another experiment, a student added a small amount of $Zn(NO_3)_2(s)$ to a saturated solution of $Zn(OH)_2(aq)$ at 25°C. The mixture was stirred thoroughly to dissolve the sample of $Zn(NO_3)_2(s)$. Assume that the volume of the solution remained constant. After the addition of $Zn(NO_3)_2(s)$, do you predict that the value of $[OH^{-}]$ will decrease, increase, or remain the same? Justify your answer in terms of the common-ion effect.

7. (continued)



(f) A student added a small amount of $HNO_3(aq)$ to a saturated solution of $Ca(OH)_2(aq)$. The mixture was stirred thoroughly. As a result, all of the solid on the bottom of the beaker dissolved, as shown in the diagram above.

(i) An acid-base reaction occurred between $HNO_3(aq)$ and $Ca(OH)_2(aq)$. Write a balanced net-ionic equation for this reaction.

(ii) In terms of Le Châtelier's principle, explain how the addition of $HNO_3(aq)$ to a saturated solution of $Ca(OH)_2$ resulted in an increase in the solubility of $Ca(OH)_2$.

8. The dissolution of an ionic solid in water involves several particle-level events. Circle the correct word to make each of the following statements true.

(a) Attractive forces are <u>broken</u> between particles in the solute.

Energy is (absorbed released).

The sign of ΔH for this event is (positive negative).

The particles become (less more) dispersed.

The sign of ΔS for this event is (positive negative).

(b) Attractive forces are <u>formed</u> between particles of the solute and the solvent.

Energy is (absorbed released).

The sign of ΔH for this event is (positive negative).

The particles become (less more) dispersed.

The sign of ΔS for this event is (positive negative).