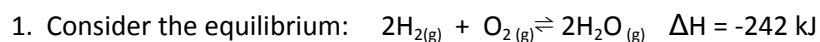
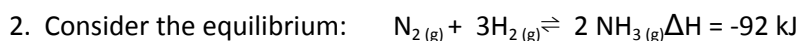


## UNITS 4 AND 5: EQUILIBRIUM THEORY & APPLICATIONS



What would happen to the equilibrium concentrations of each of the substances when the following changes are made?

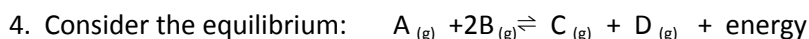
- a) increasing  $[\text{H}_2\text{O}]$   $[\text{H}_2] \uparrow$   $[\text{O}_2] \uparrow$   $[\text{H}_2\text{O}]_{\text{net}} \uparrow \text{slightly}$
- b) increasing the temperature  $[\text{H}_2] \uparrow$   $[\text{O}_2] \uparrow$   $[\text{H}_2\text{O}]_{\text{net}} \downarrow$
- c) increasing the volume of the container  $[\text{H}_2]_{\text{net}} \downarrow \text{slightly}$   $[\text{O}_2]_{\text{net}} \downarrow \text{slightly}$   $[\text{H}_2\text{O}]_{\text{net}} \downarrow$
- d) increasing the pressure  $[\text{H}_2]_{\text{net}} \uparrow \text{slightly}$   $[\text{O}_2]_{\text{net}} \uparrow \text{slightly}$   $[\text{H}_2\text{O}]_{\text{net}} \uparrow$



What conditions will increase the equilibrium concentration of ammonia?  $\downarrow T$ ,  $\uparrow P$ ,  $\uparrow$  either reactant [ ]

3. Describe the 5 characteristics of a reaction system that is at equilibrium.

From ET01: The system is closed. The forward reaction rate equals the reverse reaction rate. The concentration of the reactants and products are constant.. The temperature and pressure remain constant. The same equilibrium state can be reached by starting with reactant or products.



What affect (if any) do the following changes have on the concentrations of A, B, C and D?

- a) increase  $[\text{D}]$   $[\text{A}]_{\text{net}} \uparrow$ ,  $[\text{B}]_{\text{net}} \uparrow$ ,  $[\text{C}]_{\text{net}} \downarrow$ ,  $[\text{D}]_{\text{net}} \uparrow \text{slightly}$
- b) decrease temperature  $[\text{A}]_{\text{net}} \downarrow$ ,  $[\text{B}]_{\text{net}} \downarrow$ ,  $[\text{C}]_{\text{net}} \uparrow$ ,  $[\text{D}]_{\text{net}} \uparrow$
- c) decrease volume (increase pressure)  $[\text{A}]_{\text{net}} \uparrow \text{slightly}$ ,  $[\text{B}]_{\text{net}} \uparrow \text{slightly}$ ,  $[\text{C}]_{\text{net}} \uparrow$ ,  $[\text{D}]_{\text{net}} \uparrow$

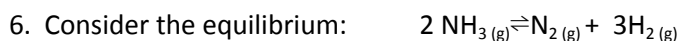


At equilibrium,  $[\text{PCl}_5] = 0.235 \text{ mol/L}$  and  $[\text{PCl}_3] = 0.174 \text{ mol/L}$ . Calculate the concentration of chlorine at equilibrium.  
 $0.174 \text{ mol/L}$

$$K_{eq} = \frac{[\text{Products}]}{[\text{Reactants}]} = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]}$$

$$0.129 = \frac{[0.174 \text{ mol/L}][\text{Cl}_2]}{[0.235 \text{ mol/L}]}$$

$$[\text{Cl}_2] = 0.17422 \text{ mol/L}$$



When 15 g of ammonia is placed in a 5.0 L container and equilibrium is established, the concentration of nitrogen is determined to be 0.070 mol/L.

a) Calculate the initial concentration of ammonia.  $0.176 \text{ mol/L}$  (0.18 mol/L sig fig)

b) Calculate the equilibrium constant (K) value.  $0.50$  (0.41 if 0.18 mol/L was used)

7. What anion can be used to separate  $\text{Li}^+_{(aq)}$  from  $\text{Pb}^{2+}_{(aq)}$ ? Any of:  $\text{Cl}^-/\text{Br}^-/\text{I}^-/\text{SO}_4^{2-}/\text{OH}^-/\text{PO}_4^{3-}/\text{CO}_3^{2-}$

8. The solubility of  $\text{Mg}(\text{OH})_2$  is  $9.12 \times 10^{-3} \text{ g/L}$ . Calculate the solubility product ( $K_{sp}$ ) value.  $1.52 \times 10^{-11}$  Hint: You must calculate molarity in mol/L

9. If 19.6 g of  $\text{BaI}_2(s)$  is dissolved in 2.5 L of a  $3.0 \times 10^{-11} \text{ CuNO}_3(aq)$  solution, will a precipitate form? ( $K_{sp}(\text{CuI}) = 1.1 \times 10^{-12}$ )  
 $Q = 1.2 \times 10^{-12}$  since  $Q > K_{sp}$  a precipitate forms Hint: You must create the ionic equation for CuI and look at the number of moles required to create the precipitate

10. The  $K_{sp}$  value for barium sulfate is  $1.5 \times 10^{-9}$ . Calculate the maximum mass of  $\text{BaSO}_4(s)$  that will fully dissolve in 3.0 L of water.  $2.8 \times 10^{-2} \text{ g}$

11. a) Calculate the hydronium and hydroxide concentrations in a solution made by dissolving 4.00 g of NaOH in 10.0 L of water.  $[\text{H}_3\text{O}^+] = 1.00 \times 10^{-12} \text{ mol/L}$  and  $[\text{OH}^-] = 0.0100 \text{ mol/L}$

b) What is the pH and pOH of the solution?  $\text{pOH} = 2.000$  and  $\text{pH} = 12.000$

12. Calculate the hydronium and hydroxide concentrations in a solution made mixing 60.0 mL of 0.400 mol/L HCl and 50.0 mL of 0.400 mol/L NaOH.  $[\text{H}_3\text{O}^+] = 0.0363 \text{ mol/L}$  and  $[\text{OH}^-] = 2.15 \times 10^{-13} \text{ mol/L}$

13. What is the hydronium and hydroxide concentration of pure water at  $10^\circ\text{C}$

$K_w = 2.95 \times 10^{-15}$  at  $10^\circ\text{C}$   $[\text{H}_3\text{O}^+] = [\text{OH}^-] = 5.43 \times 10^{-8} \text{ mol/L}$

14. If 20.0 mL of 0.050 mol/L  $\text{HCl}_{(aq)}$  is required to neutralize 80.0 mL of  $\text{NaOH}_{(aq)}$ , determine the concentration of the base.  $[\text{NaOH}] = 1.25 \times 10^{-2} \text{ mol/L}$

15. In a titration, 1.60 g of an unknown acid "HX" is dissolved in 50.0 mL water and titrated with base. If 70.0 mL of 0.200 mol/L NaOH is required to reach the endpoint, calculate the molar mass of HX.  $M = 114 \text{ g/mol}$

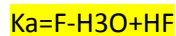
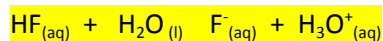
16. What is the percentage by mass (% m/m) of acetic acid (ethanoic acid;  $\text{CH}_3\text{COOH}$ ) in a sample of vinegar if 45.00 mL of 0.500 mol/L NaOH is required to titrate a 25.00 mL sample of the vinegar to the phenolphthalein endpoint.  
 $D_{\text{vinegar}} = 1.06 \text{ g/mL}$  % m/m = 5.09%

17. A 0.020 mol/L solution of a weak acid "HA" has a pH of 2.80. Find the  $K_a$  of the acid.  $K_a = 1.3 \times 10^{-4}$

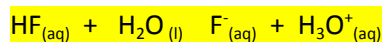
18. Given benzoic acid has a  $K_a = 7.0 \times 10^{-5}$ , calculate the  $[\text{H}_3\text{O}^+]$  for a 0.0085 mol/L solution of this weak acid.  $[\text{H}_3\text{O}^+] = 7.7 \times 10^{-4} \text{ mol/L}$

19. A 1.0 L solution is prepared by dissolving 0.20 mol HF and 1.0 mol KF.

a) Write the Bronsted-Lowry acid-base equation of HF reacting with water and write the  $K_a$  equation.



b) Create an ICE table. Assume that KF dissociates 100%.



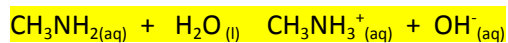
	HF	H <sub>2</sub> O	F <sup>-</sup>	H <sub>3</sub> O <sup>+</sup>
[I]	0.20	-	1.0	0
[C]	-x	-	+x	+x
[E]	0.20 - x	-	1.0 + x	x

c) Calculate the  $[\text{H}_3\text{O}^{+}]$  and pH of the solution.  $K_a = 6.67 \times 10^{-4}$

$$[\text{H}_3\text{O}^{+}] = 1.3 \times 10^{-4} \text{ mol/L}; \text{pH} = 3.87$$

20. Methylamine (aminomethane) is a weak base with  $K_b = 4.37 \times 10^{-4}$ .

a) Write the Bronsted-Lowry acid-base equation for  $\text{CH}_3\text{NH}_2$  reacting with water.



b) If a 10.0 L solution of methylamine is found to have a pH of 12.00, calculate the mass of  $\text{CH}_3\text{NH}_2$  that was dissolved to produce the solution.  $m_{\text{CH}_3\text{NH}_2} = 74.2 \text{ g}$