

Ch. Acids, Bases, and RadioactivityCommon Strong Acids

HCl	hydrochloric acid
HNO <sub>3</sub>	nitric acid
H <sub>2</sub> SO <sub>4</sub>	sulfuric acid
HClO <sub>4</sub>	perchloric acid
If #O - #H ≥ 2, then strong acid.	

Common Strong Bases

Group #1 + OH	
NaOH, KOH etc.	
Ca(OH) <sub>2</sub>	
Ba(OH) <sub>2</sub>	
Sr(OH) <sub>2</sub>	

Common Weak Acids

H <sub>3</sub> PO <sub>4</sub>	phosphoric acid
HNO <sub>2</sub>	nitrous acid
H <sub>2</sub> CO <sub>3</sub>	carbonic acid
HC <sub>2</sub> H <sub>3</sub> O <sub>2</sub> = CH <sub>3</sub> CO <sub>2</sub> H	(acetic acid)

Common Weak Bases

NH <sub>3</sub>	ammonia
CH <sub>3</sub> NH <sub>2</sub>	methyl amine
C <sub>2</sub> H <sub>5</sub> NH <sub>2</sub>	ethyl amine
** <u>H</u> <sub>2</sub> NOH	hydroxyl amine
** <u>H</u> <sub>2</sub> NNH <sub>2</sub>	hydrazine

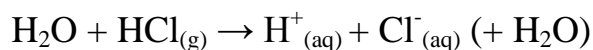
\*\* Acids: start with "H" or end in -CO<sub>2</sub>H (-COOH) and have a sour taste.

\*\* Bases: end in -OH (positive ion in front) or end in -NH, -NH<sub>2</sub>, NH<sub>3</sub>

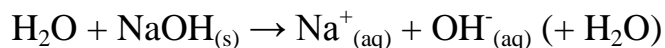
They have a bitter taste and feel slippery.

\* 3 Acid/Base TheoriesI. Arrhenius Theory

a) Acids produce H<sup>+</sup> in a water solution



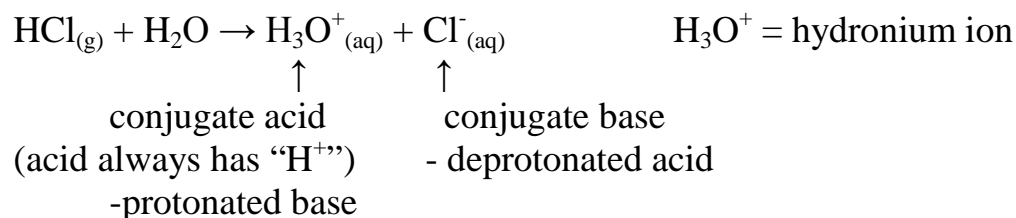
b) Bases produce OH<sup>-</sup> in a water solution



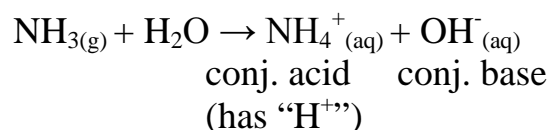
Acids, Bases and Salts are Electrolytes (Ion forming in water).

## II. Brønsted-Lowry Theory

a) Acids donate protons ( $H^+$ ) ← lose  $1e^-$ , 1 p left, 0 neutrons



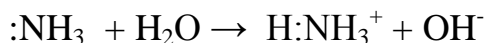
b) Bases accept protons



## III. Lewis Theory

a) Acids are  $e^-$  pair acceptors.

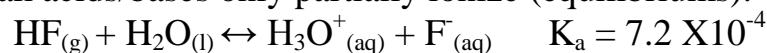
b) Bases are  $e^-$  pair donors.



\* Bases have extra electrons.

\* Strong acids/bases completely ionize (fall apart).

\* Weak acids/bases only partially ionize (equilibriums).



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{F}^-]}{[\text{HF}]}$$

The larger the  $K_a$ , the more  $\text{H}_3\text{O}^+$ , the stronger the acid.  
(The larger the  $K_b$ , the more  $\text{OH}^-$ , the stronger the base.)

Ex. 1) List the following in order of increasing acid strength:  $\text{H}_2\text{O}$ ,  $\text{HCl}$ , &  $\text{HF}$ .

\*\* $K_w = 1 \times 10^{-14}$

**$\text{H}_2\text{O}$  ( $K = 1 \times 10^{-14}$ ) <  $\text{HF}$  ( $K = 7.2 \times 10^{-4}$ ) <  $\text{HCl}$  (no  $K$ , so strong acid)**  
**smallest  $K$ , so weakest**

#90 Notes IV. pH scale

- is a measure of the acidity ( $\text{H}_3\text{O}^+$  or  $\text{H}^+$ )

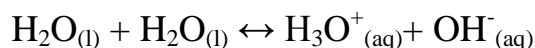
← 0 – 7 – 14 →

acid base

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

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

\*\*  $\text{H}_3\text{O}^+ = \text{H}^+$



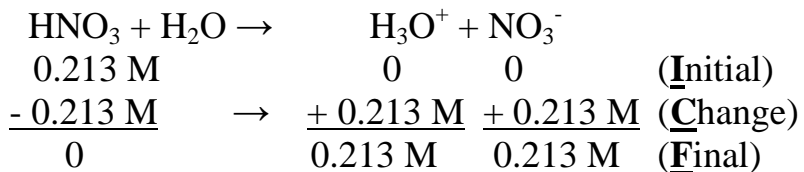
\*  $K_w = 1 \times 10^{-14} = [\text{H}_3\text{O}^+][\text{OH}^-]$

$-\log ( \quad )$

\*  $14 = \text{pH} + \text{pOH}$

Ex. 1) Find  $[\text{H}_3\text{O}^+]$ ,  $[\text{OH}^-]$ , pH, & pOH for a **strong acid**:

a) 0.213 M  $\text{HNO}_3$  (no K so strong acid)



$\text{H}_3\text{O}^+ = 0.213 \text{ M}$

$\text{pH} = -\log(\text{H}_3\text{O}^+) = -\log(0.213 \text{ M}) = -(-0.672) = \mathbf{0.672}$

$K_w = [\text{H}_3\text{O}^+][\text{OH}^-]$

$1 \times 10^{-14} = (0.213 \text{ M})(\text{OH}^-)$

$\mathbf{4.69 \times 10^{-14} \text{ M}} = [\text{OH}^-] \quad \text{pOH} = -\log(\text{OH}^-) = -\log(4.69 \times 10^{-14} \text{ M})$   
 $= -(-13.329) = \mathbf{13.329}$

\*\*The whole number is the power and is not significant!

OR

From  $\text{pH} = \mathbf{0.672}$

$\text{pH} + \text{pOH} = 14$

$0.672 + \text{pOH} = 14$

$\text{pOH} = \mathbf{13.328}$

$\text{pOH} = -\log(\text{OH}^-)$

$13.328 = -\log(\text{OH}^-)$

$-13.328 = \log(\text{OH}^-)$

move (-) before  $10^x$

$\mathbf{4.70 \times 10^{-14}} = [\text{OH}^-]$

Ex. 2) Calculate  $[\text{H}_3\text{O}^+]$  and  $[\text{OH}^-]$  from:

a)  $\text{pH} = 4.90$  ←  $\text{pH} < 7$  so acidic

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

$$4.90 = -\log [\text{H}_3\text{O}^+]$$

$$-4.90 = \log [\text{H}_3\text{O}^+] \quad \text{**move (-) before 10x}$$

$$10^x (-4.90 = \log [\text{H}_3\text{O}^+])$$

$$\mathbf{1.3 \times 10^{-5} \text{ M} = [\text{H}_3\text{O}^+]}$$

$$K_w = 1 \times 10^{-14} = (1.3 \times 10^{-5} \text{ M}) (\text{OH}^-)$$

$$\mathbf{7.7 \times 10^{-10} \text{ M} = [\text{OH}^-]}$$

b)  $\text{pOH} = 5.80$

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

$$5.80 = -\log [\text{OH}^-]$$

$$10^x (-5.80 = \log [\text{OH}^-])$$

$$\mathbf{1.6 \times 10^{-6} \text{ M} = [\text{OH}^-]}$$

$$K_w = 1 \times 10^{-14} = (\text{H}_3\text{O}^+) (1.6 \times 10^{-6} \text{ M})$$

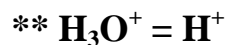
$$\mathbf{6.3 \times 10^{-9} \text{ M} = [\text{H}_3\text{O}^+]}$$

Is this acidic or basic?  $\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log 6.3 \times 10^{-9} \text{ M} = \mathbf{8.20}$  ( $\text{pH} > 7$  so, basic)

Or look at  $[\text{H}_3\text{O}^+]$  and  $[\text{OH}^-]$ :

if  $[\text{H}_3\text{O}^+]$  is larger, it is acidic,

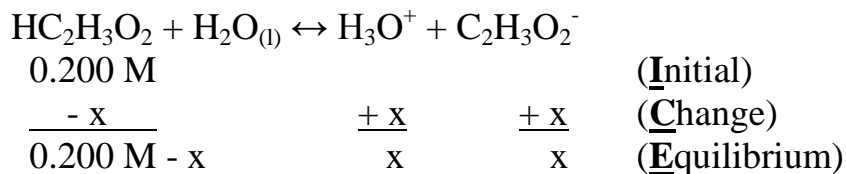
if  $[\text{OH}^-]$  is larger, it is basic.



#91 Notes V. Weak Acids/ Bases

-only partially ionize (equilibrium)

Ex. 1) What is the pH of a 0.200 M solution of acetic acid ( $\text{CH}_3\text{COOH} = \text{HC}_2\text{H}_3\text{O}_2$ )?  
**(weak acid)** What are the major species present?  $K = 1.8 \times 10^{-5}$



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{C}_2\text{H}_3\text{O}_2^-]}{[\text{HC}_2\text{H}_3\text{O}_2]} \quad \text{no liquids: } \text{H}_2\text{O}_{(l)}$$

$$1.8 \times 10^{-5} = \frac{(x)(x)}{0.200 \text{ M} - x} \quad \text{If } K_a \text{ is smaller than the Concentration by } \underline{10^3 \text{ or more}}, \text{ assume } x \text{ is small. (} 0.200 \text{ M} - x \text{ would equal just } 0.200 \text{ M)}$$

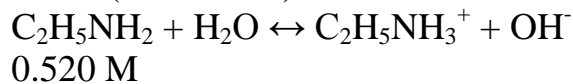
$$1.8 \times 10^{-5} = \frac{x^2}{0.200 \text{ M}}$$

$$1.9 \times 10^{-3} \text{ M} = x = [\text{H}_3\text{O}^+] = [\text{C}_2\text{H}_3\text{O}_2^-]$$

$$\text{pH} = -\log(1.9 \times 10^{-3}) = 2.72$$

$$[\text{HC}_2\text{H}_3\text{O}_2] = 0.200 \text{ M} - x = 0.198 \text{ M}$$

Ex. 2) What is the pH of a 0.520 M solution of ethyl amine,  $\text{C}_2\text{H}_5\text{NH}_2$ ?  
**(weak base)**  $K = 5.6 \times 10^{-4}$



$$K_b = \frac{[\text{C}_2\text{H}_5\text{NH}_3^+][\text{OH}^-]}{[\text{C}_2\text{H}_5\text{NH}_2]}$$

$$5.6 \times 10^{-4} = \frac{(x)(x)}{(0.520 - x)} \quad x \text{ is small}$$

$$5.6 \times 10^{-4} = \frac{x^2}{(0.520)}$$

$$1.71 \times 10^{-2} = x = \text{OH}^-$$

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

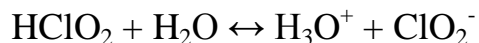
$$\text{or } K_w = [\text{H}_3\text{O}^+][\text{OH}^-]$$

$$\text{pOH} = 1.77 \quad 14 = \text{pH} + \text{pOH}$$

$$14 - 1.77 = 12.23 = \text{pH}$$

Ex. 3) What is the pH of a 0.340 M solution of HClO<sub>2</sub> (chlorous acid)

$$K \text{ of HClO}_2 = 1.2 \times 10^{-2}$$



0.340 M

$$\begin{array}{ccc} \frac{-x}{0.340 - x} & \frac{+x}{x} & \frac{+x}{x} \end{array}$$

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{ClO}_2^-]}{[\text{HClO}_2]}$$

$$1.2 \times 10^{-2} = \frac{(x)(x)}{(0.340 - x)} \quad x \text{ is not small}$$

(3.40 X10<sup>-1</sup>)

$$0.012(0.340 - x) = x^2$$
$$0.00408 - 0.012x - x^2 = 0$$

$$a = -1$$

$$b = -0.012$$

$$c = 0.00408$$

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\frac{-(-0.012) \pm \sqrt{(-0.012)^2 - 4(-1)(0.00408)}}{2(-1)}$$

$$\frac{0.012 \pm \sqrt{0.000144 + 0.01632}}{-2}$$

$$\frac{0.012 \pm \sqrt{0.016464}}{-2}$$

$$\frac{0.012 \pm 0.1283}{-2} = \frac{0.1403}{-2} \text{ or } \frac{-0.1163}{-2}$$

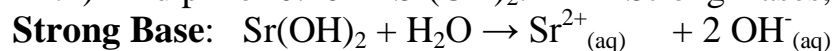
$$x = -0.070 \text{ or } \mathbf{0.058}$$

negative concentrations are impossible!

$$[\text{H}_3\text{O}^+] = x = \mathbf{0.058 \text{ M}}, \quad \text{pH} = -\log [\text{H}_3\text{O}^+] = \mathbf{1.24}$$

$$\text{check: } K_a = \frac{(0.058)(0.058)}{(0.340 - 0.058)} = 1.19 \times 10^{-2} \approx 1.2 \times 10^{-2}$$

Ex.4) Find pH of 0.10 M Sr(OH)<sub>2</sub>. **\*\*Strong Bases, like strong acids completely fall apart.**



0.10 M

-0.10 M

0

[OH<sup>-</sup>] = 0.20 M

+0.10 M + 2(0.10M)

0.10 M    0.20 M

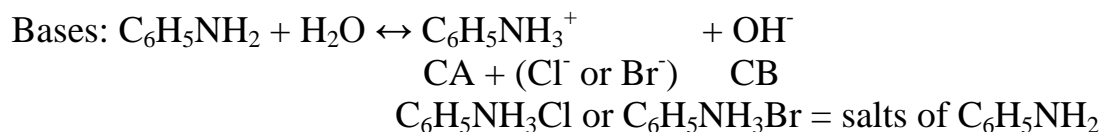
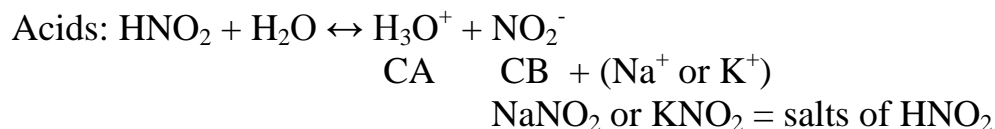
pOH = - log [OH<sup>-</sup>] = 0.70    14 - pOH = **pH = 13.30**

#92 Notes Ch. Aqueous Equilibria

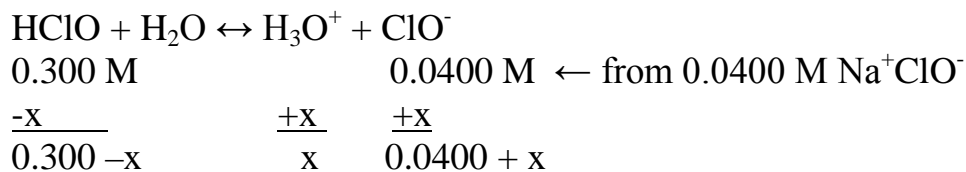
I. Buffered Solutions

-resist changes in pH.

A buffered solution may contain a weak acid with its salt (CB) or a weak base with its salt (CA).



Ex.1) What is the pH of a 0.300 M solution of HClO buffered with 0.0400 M NaClO?  
K of HClO = 3.5 X 10<sup>-8</sup>



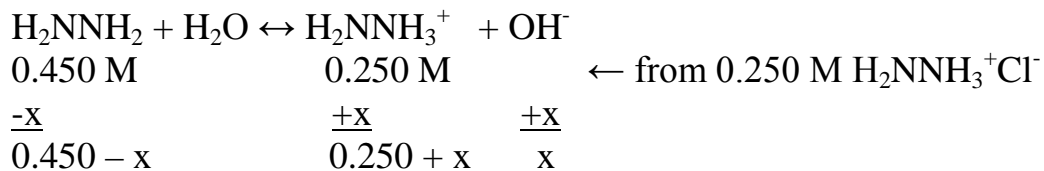
$$3.5 \times 10^{-8} = \frac{(x)(0.0400 + x)}{(0.300 - x)} \quad \text{x is small}$$

$$3.5 \times 10^{-8} = \frac{(x)(0.0400)}{(0.300)}$$

$$2.6 \times 10^{-7} = x = [\text{H}_3\text{O}^+] \quad \text{pH} = -\log [\text{H}_3\text{O}^+] = \mathbf{6.58}$$



Ex. 2) What is the pH of a solution containing 0.450 M  $\text{H}_2\text{NNH}_2$  and 0.250 M  $\text{H}_2\text{NNH}_3\text{Cl}$ .  
K of  $\text{H}_2\text{NNH}_2 = 3.0 \times 10^{-6}$



$$3.0 \times 10^{-6} = \frac{(0.250 + x)(x)}{(0.450 - x)} \qquad \text{x is small}$$

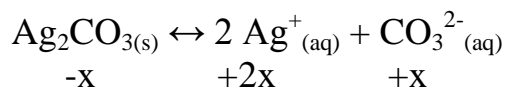
$$3.0 \times 10^{-6} = \frac{(0.250)(x)}{(0.450)}$$

$$\begin{aligned} 5.4 \times 10^{-6} &= x = [\text{OH}^-] \\ \text{pOH} &= -\log [\text{OH}^-] = 5.27 \\ \text{pH} &= 14 - \text{pOH} = \mathbf{8.73} \end{aligned}$$

## #93 Notes II. Solubility Equilibria

- describes the amount of solid that dissolves in a saturated solution  
(no more solid will dissolve).

Ex. 1) Calculate the solubility of  $\text{Ag}_2\text{CO}_3$  in mols per liter.  $K_{\text{sp}} = 8.1 \times 10^{-12}$



$$K_{\text{sp}} = [\text{Ag}^+]^2 [\text{CO}_3^{2-}]^1$$

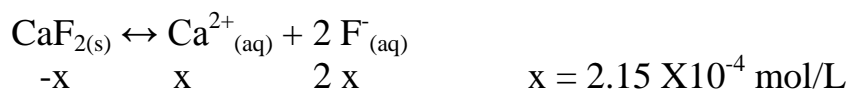
$$K_{\text{sp}} = (2x)^2 (x)^1$$

$$K_{\text{sp}} = 4x^3$$

$$8.1 \times 10^{-12} = 4x^3$$

$$1.3 \times 10^{-4} \text{ M} = x \quad \quad \quad \mathbf{1.3 \times 10^{-4} \text{ mol/L}}$$

Ex. 2) Calculate the  $K_{\text{sp}}$  of  $\text{CaF}_2$ , if its solubility is  $2.15 \times 10^{-4} \text{ mol/L}$ .



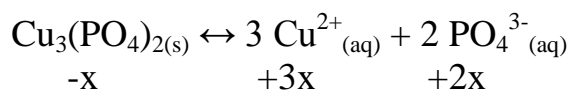
$$K_{\text{sp}} = [\text{Ca}^{2+}]^1 [\text{F}^-]^2$$

$$K_{\text{sp}} = (x)^1 (2x)^2$$

$$K_{\text{sp}} = 4x^3$$

$$K_{\text{sp}} = 4 (2.15 \times 10^{-4} \text{ mol/L})^3 = \mathbf{3.97 \times 10^{-11}}$$

Ex. 3) Calculate the solubility of  $\text{Cu}_3(\text{PO}_4)_2$  in mol/L.  $K_{\text{sp}} = 8.4 \times 10^{-15}$



$$K_{\text{sp}} = [\text{Cu}^{2+}]^3 [\text{PO}_4^{3-}]^2$$

$$K_{\text{sp}} = (3x)^3 (2x)^2$$

$$K_{\text{sp}} = (27 x^3) (4 x^2)$$

$$K_{\text{sp}} = 108 x^5$$

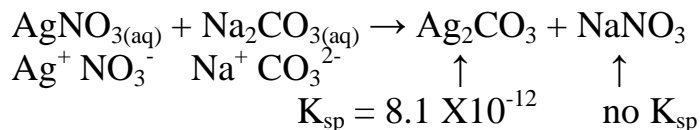
$$8.4 \times 10^{-15} = 108 x^5$$

$$7.8 \times 10^{-17} = x^5$$

$$\mathbf{6.0 \times 10^{-4} \text{ mol/L} = x}$$

#94 Notes III. Precipitation Reactions

Ex.1) Will a precipitate form, if 25 ml of 0.100 M AgNO<sub>3</sub> is added to 105 ml of 0.200 M Na<sub>2</sub>CO<sub>3</sub>?



a) Find concentration of ions in new volume: 25 ml + 105 ml = 130 ml (new solution)

ML = ML

$$(0.100 \text{ M AgNO}_3) (25 \text{ ml}) = M (130 \text{ ml})$$

$$\mathbf{0.0192 \text{ mol/L}} = M_{\text{AgNO}_3}$$

$$\begin{array}{cc} \frac{X1\text{Ag}^+}{\mathbf{0.0192 \text{ M Ag}^+}} & \frac{X1\text{NO}_3^-}{\mathbf{0.0192 \text{ M NO}_3^-}} \end{array}$$

$$(0.200 \text{ M Na}_2\text{CO}_3) (105 \text{ ml}) = M (130 \text{ ml})$$

$$\mathbf{0.162 \text{ mol/L}} = M_{\text{Na}_2\text{CO}_3}$$

$$\begin{array}{cc} \frac{X2\text{Na}^+}{\mathbf{0.324 \text{ M Na}^+}} & \frac{X1\text{CO}_3^{2-}}{\mathbf{0.162 \text{ M CO}_3^{2-}}} \end{array}$$

b) Put concentrations into K<sub>sp</sub> equation:



$$K_{\text{sp}} = [\text{Ag}^+]^2 [\text{CO}_3^{2-}]^1 = (0.0192 \text{ M Ag}^+)^2 (0.162 \text{ M CO}_3^{2-})^1 = 5.97 \times 10^{-5}$$

$$\mathbf{K_{\text{sp}} \text{ calculated} = 5.97 \times 10^{-5} \gg \gg \text{Real } K_{\text{sp}} \text{ from book} = 8.1 \times 10^{-12}}$$

**for a saturated solution**

**since K<sub>sp</sub> is more than saturated, solid forms (precipitate)**

If the K<sub>sp</sub> calculated is less than the real K<sub>sp</sub>,  
it is less than saturated (not full), so no solid forms.

## #95 Notes Ch. Radiochemistry

The “attractive” nuclear force between protons and neutrons is usually stronger than the repulsion energy of the protons. But some isotopes have too many protons and not enough neutrons, so there is too much repulsion. These atoms are unstable (radioactive). Atoms with more than 83 protons are always unstable (atomic #'s > 83).

### I. Nuclear Decay Reactions (to become stable)

alpha ( $\alpha$ ) particle  ${}_2^4\text{He}$  -barely passes through paper

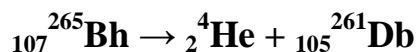
beta ( $\beta$ ) particle  ${}_{-1}^0\text{e}$  - stopped by 3 mm Al or 10 mm wood

gamma ( $\gamma$ ) is electromagnetic energy - stopped by 60 cm Al or 7cm Pb

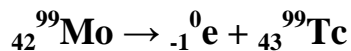
positron particle  ${}_{+1}^0\text{e}$

emission (given off), so put particle on product side  
capture (taken in), so put particle on the reactant side

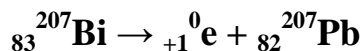
Ex. 1)  ${}^{265}\text{Bh}$  decays by  $\alpha$ -emission.



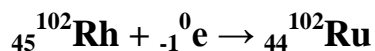
Ex. 2)  ${}^{99}\text{Mo}$  decays by  $\beta$ -emission ( $\beta^-$ ).



Ex. 3)  ${}^{207}\text{Bi}$  decays by positron emission ( $\beta^+$ ).



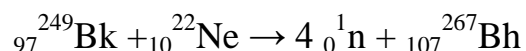
Ex. 4)  ${}^{102}\text{Rh}$  decays by electron capture (e.c. or  $\epsilon$ ).



### II. Bombardments

-linear or cyclotron particle accelerators can be used to combine smaller atoms into larger atoms or to break up large atoms into smaller atoms.

Ex. 1)  ${}^{249}\text{Bk}$  is bombarded by  ${}^{22}\text{Ne}$  to make a new heavier element and 4 neutrons ( ${}_0^1\text{n}$ ).  
Write the reaction.



#96 Notes III. Half-lives

A half-life is the time it takes for 1/2 of a sample of a radioactive material to decay into something else.

The rate of radioactive decay reactions is 1<sup>st</sup> order, so

$$\text{Rate} = k [A]^1 \quad \leftarrow \text{decays/sec}$$

$$t_{1/2} = 0.693 / k \quad \{t_{1/2} \text{ is the half-life (not } t \div 2)\}$$

$$\begin{array}{ccc} \ln [A] & = & -kt + \ln [A]_0 \quad \{ \text{order in textbook equation may be } \ln [A]_0 = kt + \ln [A] \} \\ \uparrow & & \uparrow \\ \text{amount left after} & & \text{initial} \\ \text{time} = t & & \text{amount} \end{array}$$

Ex. 1) 28 g of <sup>87</sup>Sr has a 1/2 life of 2.8 hrs.

a) Find the decays/sec (decays = atoms).

$$\begin{array}{l} \text{Rate} = k [A]^1 \qquad t_{1/2} = 0.693 / k \qquad \frac{2.8 \text{ hr} \mid 3600 \text{ sec}}{\mid 1 \text{ hr}} = 10080 \text{ sec} \\ 10080 \text{ sec} = 0.693 / k \\ (10080) k = 0.693 \\ k = 6.875 \times 10^{-5} \text{ sec}^{-1} \end{array}$$

$$\text{Rate} = k [A]^1 = (6.875 \times 10^{-5} \text{ sec}^{-1}) \left( \frac{28 \text{ g } ^{87}\text{Sr} \mid 1 \text{ mol} \mid 6.022 \times 10^{23} \text{ atoms}}{\mid 87 \text{ g} \mid 1 \text{ mol}} \right)$$

$$\text{Rate} = 1.3 \times 10^{19} \text{ decays/sec}$$

b) How much is left after 4.0 hrs?

$$\begin{array}{l} t_{1/2} = 2.8 \text{ hr} \qquad t_{1/2} = 0.693 / k \\ 2.8 \text{ hr} = 0.693 / k \\ (2.8) k = 0.693 \\ k = 0.2475 \text{ hr}^{-1} \end{array}$$

$$\begin{array}{l} \ln A = -kt + \ln A_0 \\ \ln A = -(0.2475 \text{ hr}^{-1}) (4.0 \text{ hr}) + \ln (28 \text{ g}) \\ \ln A = -0.99 + 3.33 \\ e^x (\ln A = 2.34) \\ \mathbf{A = 10. g \text{ is left}} \end{array}$$

c) How much decayed in 4.0 hrs?

$$28 \text{ g } \{initially\} - 10. \text{ g } \{left\} = \mathbf{18 \text{ g decayed}}$$

Ex.2) How long does it take for 62.3% of  $^{133}\text{Xe}$  to decay? ( $t_{1/2}$  = 5.3 days)

$$t_{1/2} = 0.693/k$$

$$5.3 \text{ d} = 0.693/k$$

$$(5.3 \text{ d}) k = 0.693$$

$$k = 0.131 \text{ d}^{-1}$$

$$100\% \text{ initially} = [\text{A}]_0$$

$$\underline{-62.3\% \text{ decays}}$$

$$37.7\% \text{ is left} = [\text{A}]$$

$$\ln [\text{A}] = -kt + \ln [\text{A}]_0$$

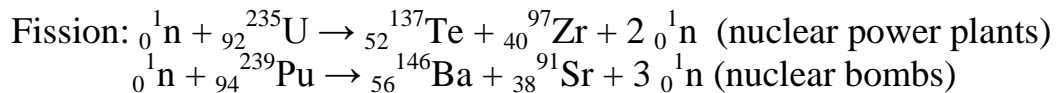
$$\ln (37.7) = -(0.131 \text{ d}^{-1}) t + \ln (100)$$

$$3.63 = -0.131t + 4.605$$

$$-0.975 = -0.131t$$

$$\mathbf{7.4 \text{ d} = t}$$

#97 Notes IV. Nuclear Fission / Fusion  
(splitting/ breaking apart) (combining)

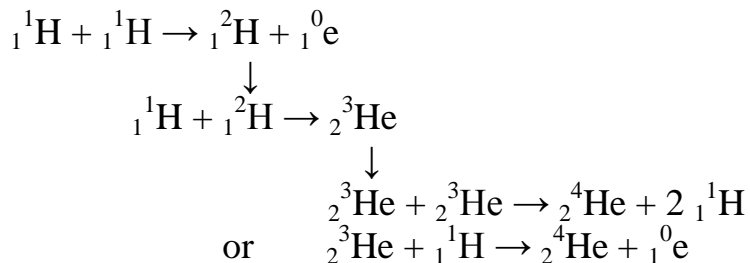


Subcritical mass: the reaction dies out.

Critical mass: for each neutron that reacts, one neutron that is produced, causes a reaction.

Supercritical mass: exponential increase, explosion.

Fusion on the sun:



In Fission and Fusion reactions some mass is lost and converted to energy!  $E = mc^2$

V. Nuclear Power Plants

1) Fuel:  ${}_{92}^{235}\text{U}$  &  ${}_{94}^{239}\text{Pu}$  (produced in the reaction)

2) Moderator:  $\text{H}_2\text{O}$ , heavy  $\text{H}_2\text{O}$ , graphite, Be  
-slows down neutrons, but does not absorb them.

3) Control Rods: B, Cd, or Ga alloyed with Al or steel  
-absorbs excess neutrons not needed to keep the chain reaction going.

4) Coolant: He,  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ , liquid metals (Na)  
-removes heat from the reactor.

5) Heat Exchanger:  
-transfers heat from the hot coolant, to the cool water, that will make steam to turn the turbines.

6) Safety Shields: Pb or thick concrete  
-radiation shield around the reactors.

**\*End of Notes\*** (Assignments #98-99 are Review Assignments. There are no notes for these assignments.)