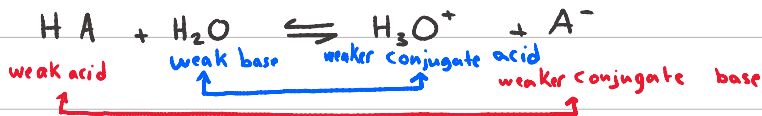


♥ equilibria A-level ♥

Bronsted lowry acid → proton donor

base → proton acceptor



conjugate pairs: HA and A⁻

H₂O and H₃O⁺

H₂O is amphoteric

can act as

acid or base

weak acid → stronger C. base

weak base → stronger C. acid



Calculating pH for a strong acid or base

strong acid

H⁺, H₃O⁺, HCl,
HBr, HI,

HNO₃, H₂SO₄

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



Strong base

OH⁻, NaOH, KOH...

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

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

$$[\text{H}^+] * [\text{OH}^-] = 10^{-14}$$

dissociation constant for water K_w

calculating pH for a weak acid.

(incomplete dissociation)

step 1: write dissociation equation with water



step 2: write dissociation constant with water (K_a)

$$K_a = \frac{[\text{products}]}{[\text{Reactants}]} = \frac{[\text{HCOO}^-] * [\text{H}_3\text{O}^+]}{[\text{HCOOH}]}$$

same concentration

$$K_a = \frac{[x]^2}{[\text{HCOOH}]}$$



x is the $[\text{H}_3\text{O}^+]$

step 3: find pH

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

same as H_3O^+

<https://aseelkhatib.com/chemistry-resources>



practice question

- (i) Write an expression for the acid dissociation constant, K_a , for butanoic acid, $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$. $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^- + \text{H}_3\text{O}^+$

$$K_a = \frac{[\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}]}$$

← same concentration

[1]

- (ii) The $\text{p}K_a$ of $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ is 4.82. ← convert $\text{p}K_a$ to K_a .

A solution of $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}(\text{aq})$ has a pH of 3.25. ← we can find $[\text{H}_3\text{O}^+]$

Calculate the concentration, in mol dm^{-3} , of $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ in this solution.

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

$$3.25 = -\log [\text{H}^+] \quad [\text{H}^+] = 5.62 \times 10^{-4}$$

$$\star \text{ p}K_a = -\log K_a$$

$$4.82 = -\log K_a \quad K_a = 1.51 \times 10^{-5}$$

$$\star 1.51 \times 10^{-5} = \frac{[5.62 \times 10^{-4}]^2}{[\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}]}$$

$$= 0.021 \text{ mol dm}^{-3}$$



Buffer Solutions

A Buffer resists the change of pH when small amount of strong acid or base is added.

Acidic Buffer: $\text{pH} < 7$ weak acid + conjugate base

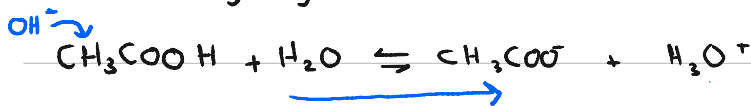
Alkaline Buffer: $\text{pH} > 7$ weak base + conjugate acid

* How does buffer maintain acidity.

* adding acid to buffer, the added H^+ reacts with c. base, more CH_3COOH forms as equilibrium shifts to left, pH decreases slightly



* adding a base to buffer solution, the added OH^- reacts with weak acid CH_3COOH , equilibrium shifts to right to produce more CH_3COO^- , pH increases slightly.



Buffers in blood. (HCO_3^-)



if pH increases ($[\text{H}^+]$ decreases), equilibrium shifts to right to produce more H^+

if pH decreases ($[\text{H}^+]$ increases), equilibrium shifts to left, to remove some H^+

Buffer calculations:

[1] if concentrations of weak acid and C. base are given

$$\text{pH} = \text{pK}_a + \log \frac{[\text{base}]}{[\text{acid}]}$$

use $C_1 V_1 = C_2 V_2$
per each value to find C_2

[2] if strong (acid or base) mixed with buffer solution, write equation use RICE then use buffer equation.

R equation

I initial amounts in moles

C - lower amount of moles $\rightarrow$ + lower amount of moles
E find moles and use buffer equation

A buffer solution of pH 5.00 is produced by adding sodium propanoate to 5.00 g of propanoic acid in 100 cm³ of distilled water.

Calculate the mass of sodium propanoate that must be used to produce this buffer solution. The K_a of propanoic acid is $1.35 \times 10^{-5} \text{ mol dm}^{-3}$.

[M_r : propanoic acid, 74.0; sodium propanoate, 96.0]

$$\text{pH} = \text{p}K_a + \log \frac{[\text{base}]}{[\text{acid}]}$$

$$\text{Conc.} = \frac{\text{mol}}{V} = \frac{\text{mass}/M_r}{V}$$

$$5 = -\log(1.35 \times 10^{-5}) + \log \frac{(x \div 96) \div 100}{(5 \div 74) \div 100}$$

$$x = 8.74 \text{ g.}$$

5.0 cm³ of 0.20 mol dm⁻³ potassium hydroxide, KOH, are added to 20.0 cm³ of 0.20 mol dm⁻³ HOBr(aq). weak acid + strong base (use RICE)

Calculate the pH of the buffer solution produced.

$$\text{moles KOH: } \frac{5}{1000} \times 0.2 = 0.001$$

$$\text{moles HOBr: } \frac{20}{1000} \times 0.2 = 0.004$$



$$\text{I } 0.001 \quad 0.004 \quad 0$$

$$\text{C } -0.001 \quad -0.001 \quad +0.001$$

$$\text{E } 0 \quad 0.003 \quad 0.001$$



w. acid and c. base $\Rightarrow$ this is buffer

$$\text{pH} = \text{p}K_a + \log \frac{[\text{base}]}{[\text{acid}]}$$

$$\text{pH} = -\log(2 \times 10^{-9}) + \log \frac{0.001}{0.003}$$

same volume,
no need to convert
to concentration.

$$\text{pH} = 8.2$$

* Solubility product K_{sp} :

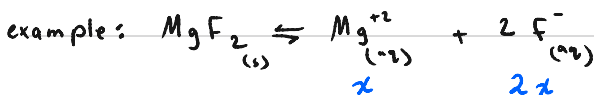
the equilibrium constant for the equilibrium between a sparingly soluble ionic solid and its ions in a saturated solution at a constant temperature.



$$K_{sp} = [\text{Ag}^+][\text{Cl}^-]$$

K_{sp} calculations

step 1 write equilibrium equation, and show the molar concentration of each ion (solubility)



step 2: write K_{sp} expression

$$K_{sp} = [\text{Mg}^{2+}] \times [\text{F}^-]^2$$

step 3: plug in solubility for each ion

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

units:

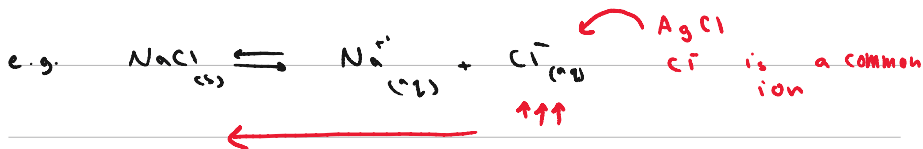
depends on molar solubilities

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

unit: mol dm^{-3}



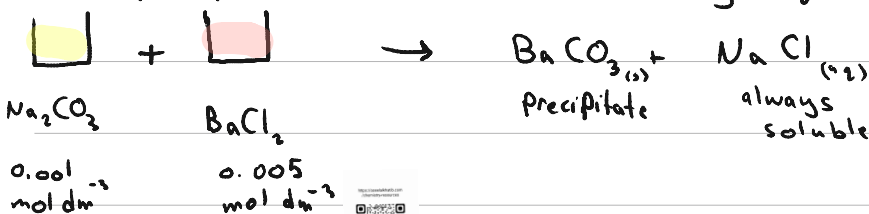
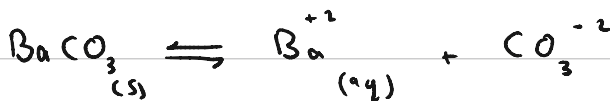
* **The common ion effect** : solubility decreases when an ion that is common with a dissolving salt is added to the solution.



equilibrium shifts to left forming more salt.

predicting precipitation :

will precipitate form when mixing equal volumes



$$K_{sp} = \underbrace{[\text{Ba}^{+2}]}_{\substack{\downarrow \\ 0.005 \\ 2}} \underbrace{[\text{CO}_3^{-2}]}_{\substack{\downarrow \\ 0.001 \\ 2}}$$

concentrations halved

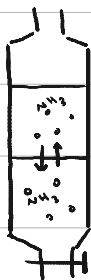
because volume is

doubled when mixing

if answer $>$ K_{sp} given then ppt will form

*partition coefficients:

is a ratio of concentration of a solute in two solvents.



$$K_{pc} = \frac{[NH_3] \text{ in organic solvent}}{[NH_3] \text{ in water}}$$

if $K_{pc} > 1$ NH_3 is more soluble in organic

$K_{pc} < 1$ NH_3 is more soluble in water

Steps to solve for K_{pc} :

1. sketch a diagram, label all given information

2. Check solute starts with a solvent then mixed with other solvent, some of solute will move and dissolve with the other solvent.

3. divide moles or masses of each solvent layers by the volumes

<https://www.mathsisgood.com/chemistry/revision>

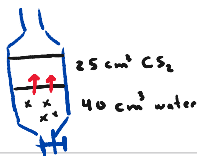


practice question

The partition coefficient, K_{pc} , for a compound, X , between carbon disulfide, CS_2 , and water is 10.5.

1.85 g of X is dissolved in water and made up to 100.0 cm^3 in a volumetric flask. 40.0 cm^3 of this aqueous solution is shaken with 25.0 cm^3 of CS_2 . The mixture is left to reach equilibrium.

Calculate the mass of X , in g, extracted into the CS_2 layer.



1.85 g X $\xrightarrow{\text{dissolved in}}$ 100 cm^3 water

?? $\xleftarrow{\quad}$ 40 cm^3 water

= 0.74 g of X dissolved in 40 cm^3 water

then mixed with CS_2 , some of X moves
from water layer to CS_2 layer.

$$K_{pc} = \frac{[X] \text{ in } CS_2}{[X] \text{ in water}} = 10.5$$
$$= \frac{(y) \div 25}{(0.74 - y) \div 40} = 10.5$$

$$y = 0.642 \text{ g}$$