

Titration

An important analytical technique, titrations are used to determine the concentration of a substance in solution by comparing it to a solution of a known concentration; called a **standard**

The reaction between the unknown and the standard is allowed to proceed until mole ratios like those in the balanced chemical equation are reached.

This stoichiometric point (sometimes called the equivalence point or end point) is determined using some sort of chemical indicator

Often these reactions are used with acids/bases, for acid/base titrations the end point is reached when:

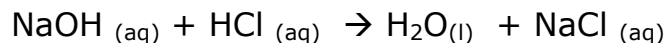
Moles of OH⁻ from the base = moles of H⁺ from the acid

Titration consists of several trials; the first is an estimate, usually done quickly to get an approximate endpoint, almost always the first trial will be over the endpoint (overshot) The average volume of the second and subsequent trials are used in calculations:

Steps to follow

- 1) Write the balanced equation (as always – you can't go wrong with this)
- 2) Calculate the moles of standard used ($n = M \times V$)
- 3) Determine the moles of unknown using the mole ratio
- 4) Calculate the unknown concentration ($M = n/V$)

Ex. If 10.0mL of HCl is titrated with 20.0mL of 0.40M NaOH, what is [HCl]?

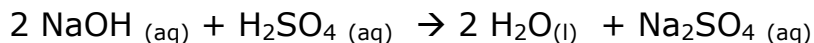


Moles of standard (in this case NaOH) = $0.40 \text{ M} \times 0.0200 \text{ L} = 8.0 \times 10^{-3}$

Moles of unknown (HCl) =

- Some acids or bases produce two (or more) H^+ or OH^- for each formula unit ($\text{H}_3\text{PO}_4 \rightarrow 3 \text{H}^+ + \text{PO}_4^{3-}$)

Ex. An average volume of 24.90mL of 0.100 M NaOH was required to neutralize 15.00mL of H_2SO_4 . What is the concentration of the acid?



Moles of standard (NaOH) =

Moles of unknown (HCl) =

[HCl] =

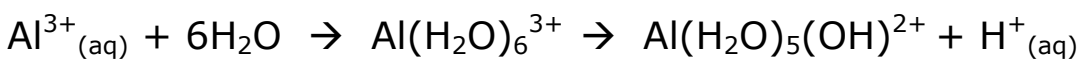
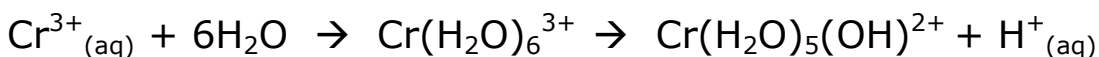
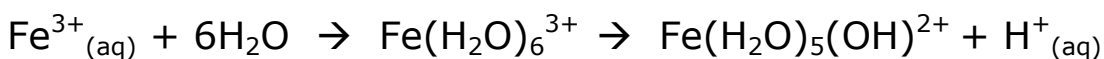
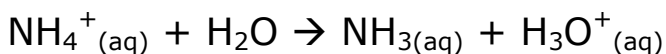
Salt Hydrolysis (reacting with water)

Dissolving salts in water sometimes yields a change in pH, as some anions and cations can interact with water and produce H^+ and/or OH^- .

Cations

Most **cations** are spectator ions, with 4 exceptions (there **are** more than 4 but we'll just do these 4 for Chemistry 12) – These **cations** act as **acids** in solution

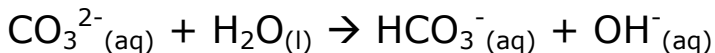
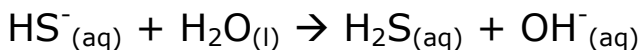
- NH_4^+ donates H^+ , the metal ions Fe^{3+} , Cr^{3+} , Al^{3+} , all form hexahydrates that can act as Brønsted-Lowry acids:



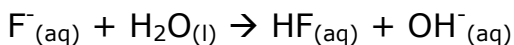
Anions

Most **anions** undergo hydrolysis as **bases**, grabbing an H^+ from water, with 6 exceptions = the conjugate bases of strong acids

No hydrolysis with Cl^- , Br^- , I^- , ClO_4^- , HSO_4^- , NO_3^-



Ex. What is the pH of a 0.100M solution of NaF?



Reaction	F^-	$+ H_2O$	\rightleftharpoons	HF	+	OH^-
[Initial]		--				
Change		--				
[Equilibrium]		--				

Ex. Two solutions contain fluoride: 1.0M KF and 1.0M HF, which has higher conductivity?

HF only partially dissociates (1/10000) so HF is present in solution 10,000 times more than H^+ and F^- . HF is not very conductive.

With KF, K^+ dissociates 100% because it's a spectator ion, where F^- reacts with water producing almost as much OH^- so KF is much more conductive.

Amphiprotic hydrolysis

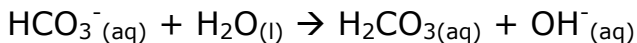
Amphiprotic ions can both donate and accept protons, so when they hydrolyze it's not always obvious as to whether a basic or acidic solution will arise.

Have to compare the K_a and the K_b . Whichever constant is larger that's what reaction occurs.

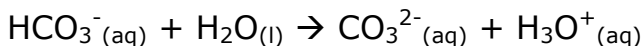
Ex. $NaHCO_3$ is dissolved in water, is the resulting solution acidic, basic or neutral?



Na^+ is a spectator, so we're left with HCO_3^- . The question is will the HCO_3^- behave as an acid or a base?



Or



Compare K_a and K_b

$$K_a = 5.6 \times 10^{-11}$$

NOTICE THAT THE K_a used is for the CONJUGATE ACID!

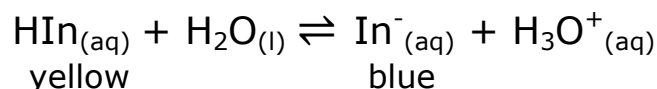
$K_b > K_a \quad \therefore$ acts AS A BASE!

Ex. NH_4F is dissolved in water, is the resulting solution acidic, basic or neutral?

NH_4^+ (acting as an acid) and F^- (acting as a base)

Indicators

An indicator is a weak acid/base where the acid form has a different colour from the base form.



For the example above, blue/yellow, this is a common indicator called bromthymol blue.

Excess of strong acid (H^+) will shift equilibrium left, forming more of the 'acid form' - protonated (yellow) whereas excess base (OH^-) will shift right producing more of the 'base form' - deprotonated (blue).

End Point

End Point \equiv the point where $[\text{H}^+] = [\text{OH}^-]$ (acid = base)

For an indicator... if $[\text{H}^+] = [\text{OH}^-]$ then $[\text{HIn}] = [\text{In}^-]$

Ex. Bromthymol blue [yellow] = [blue] \rightarrow green!

$$K_a(\text{In}) = \frac{[\text{In}^-][\text{H}^+]}{[\text{HIn}]}$$

So @ Endpoint, b/c $[\text{HIn}] = [\text{In}^-] \quad \therefore K_a = [\text{H}^+]$

\rightarrow pKa (at end point) = pH (of indicator)

Based on data booklet: can choose appropriate indicators for different acid/base reactions.

Ex. Some indicator is green in its acid form, and red in its base form. Its $pK_a = 4.2$ what colour is it in a 0.010 M HCN?

$K_a =$

Reaction	HCN	\rightleftharpoons	H ⁺	+	CN ⁻
[Initial]					
Change	-				
[Equilibrium]					

Assume X is small

pH =

So if indicator $pK_a =$

So it's **Red**

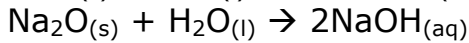
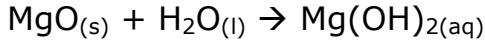
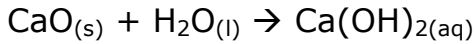
Hebden pg 162/3 #110-120

Oxides

Metal Oxides

- solids @ room temperature
- solutions >7 pH (Basic)
- Soluble oxides → strong bases

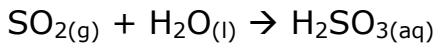
Ex.



Non-metal oxides

- Gases @ room temp.
- Solutions <7 pH (acidic)
- Major contributors to acid rain

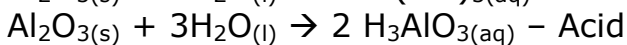
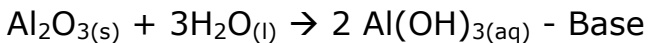
Ex.



Semi-metal oxides

- Usually solids at room temp.
- Can be basic OR acidic
- **Amphiprotic**

Ex.



hydrogen 1 H 1.0079																	helium 2 He 4.0026				
lithium 3 Li 6.941	beryllium 4 Be 9.0122											boron 5 B 10.81	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180				
sodium 11 Na 22.990	magnesium 12 Mg 24.305											aluminum 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948				
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.630	arsenic 33 As 74.922	selecnium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80				
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29				
cesium 55 Cs 132.91	barium 56 Ba 137.33	lanthanum 57 La 138.905	hafnium 71 Hf 178.49	tantalum 72 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]				
francium 87 Fr [223]	radium 88 Ra [226]	* *	actinium 89 Ac [227]	thorium 90 Th [232]	protactinium 91 Pa [231]	uranium 92 U [238]	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]	lawrencium 103 Lr [260]	unnilium 110 Uu [289]	ununium 111 Uu [288]	ununbium 112 Uu [287]	ununquadium 114 Uu [289]

Anhydride reactions

Just as acids react with bases to produce water and salt. So too can oxides react to produce a salt – but NO WATER!!!

Ex

