CHEM1011 LECTURE 4

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LEARNING OBJECTIVES - WEEK 2

After this week you should be able to:

- Define what is meant by an acid and a base.
- Know the names and formulae of common acids and bases.
- Predict the products of reactions of acids and bases with oxides, carbonates etc.
- Describe the properties which distinguish gases from other states of matter.
- Calculate properties of gases and gas mixtures using the ideal gas equation.

WHAT IS AN ACID? WHAT IS A BASE?

Acid: Corrosive? Zingy?

Vinegary? Tart? Astringent?

- Stomach Acid - HCl
- Battery Acid - H_2SO_4
- Coca Cola – H_2CO_3 and H_3PO_4

Base: Sweet? Caustic? Simple?... The bottom of something?

- Ammonia (Floor cleaner) NH_3
- Caustic Soda (Drain Cleaner) NaOH

DEFINITIONS OF ACIDS AND BASES

Arrhenius: Acids produce H^+ ions in solution, bases produce OH^- ions.

Actually…. Acids ultimately produce hydronium ions; an H^+ ion is just a single proton (tiny!) and given the abundance of water it will coordinate with a water molecule.

Chemists are inherently lazy so we use the H^+ as an approximation but keep this reaction in mind!

$$H^+_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)}$$

DEFINITIONS OF ACIDS AND BASES

Brønsted–Lowry: Acids are proton (H^+) donors, bases are proton acceptors.

Accepts H^+, becomes H_3O^+

Donates H^+, becomes Cl^-

$$HCl + H_2O \rightarrow Cl^- + H_3O^+$$

acid base

BRØNSTED-LOWRY ACIDS AND BASES (BLACKMAN 11.1)

- By definition do not require water

  For example: ammonia reacting with acetic (ethanoic) acid

Conjugate acid-base pair

$$CH_3COOH(l) + NH_3(g) \rightleftharpoons CH_3COO^-(aq) + NH_4^+(aq)$$

$CH_3COOH(l)$	$NH_3(g)$	$CH_3COO^-(aq)$	$NH_4^+(aq)$
Acid	Base	Conjugate base of AA	Conjugate acid of ammonia
Proton Donor	*Proton Acceptor*		

Conjugate acid-base pair

BRØNSTED-LOWRY ACID/BASE- IMPORTANT POINTS

1. An acid can be Positively charged, Neutral or Negatively charged but it must contain a H in it's formula.

eg H_3O^+ , NH_4^+ HCl, H_2SO_4 HPO_4^{2-}

2. Acids can be monoprotic, diprotic or triprotic (give 1, 2 or 3 protons).

Example, Carbonic Acid, H_2CO_3 (diprotic)

$$\underset{\text{Carbonic acid}}{H_2CO_3} + H_2O \rightleftharpoons \underset{\text{Bicarbonate ion}}{HCO_3^-} + H_3O^+$$

2nd Proton

$$\underset{\text{Bicarbonate ion}}{HCO_3^-} + H_2O \rightleftharpoons \underset{\text{Carbonate ion}}{CO_3^{2-}} + H_3O^+$$

BRØNSTED-LOWRY ACID/BASE- IMPORTANT POINTS

3. A Base can be negatively charged or neutral, it must contain a lone pair of electrons to bind to the H^+ ion

e.g. Cl^-, I^-, ^-OH NH_3

4. Some molecules and ions appear on both sides i.e **Amphiprotic -** can act as an acid or a base

Water can lose a proton to become OH^-
or it can gain a proton to become H_3O^+

Bicarbonate ion, HCO_3^-, can lose a proton to become carbonate ion CO_3^{2-}

Bicarbonate ion, HCO_3^-, can gain a proton to carbonic acid H_2CO_3

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THE BRØNSTED—LOWRY DEFINITION OF ACIDS AND BASES (BLACKMAN 11.1)

- For a proton to be measurably acidic, it must be bound to another atom via an appreciably acidic bond
- **Acids tend to contain protons bound to group 16 or 17 elements**
- Basic species require the presence of one or more lone pairs
- Not all species containing lone pairs act as bases
- **Bases usually contain group 15 or 16 elements, the atoms of which are often deprotonated (e.g. OH^-)**

15	16	17
7 N	8 O	9 F
15 P	16 S	17 Cl
33 As	34 Se	35 Br
51 Sb	52 Te	53 I

POSSIBLY CONFUSING MOLECULES

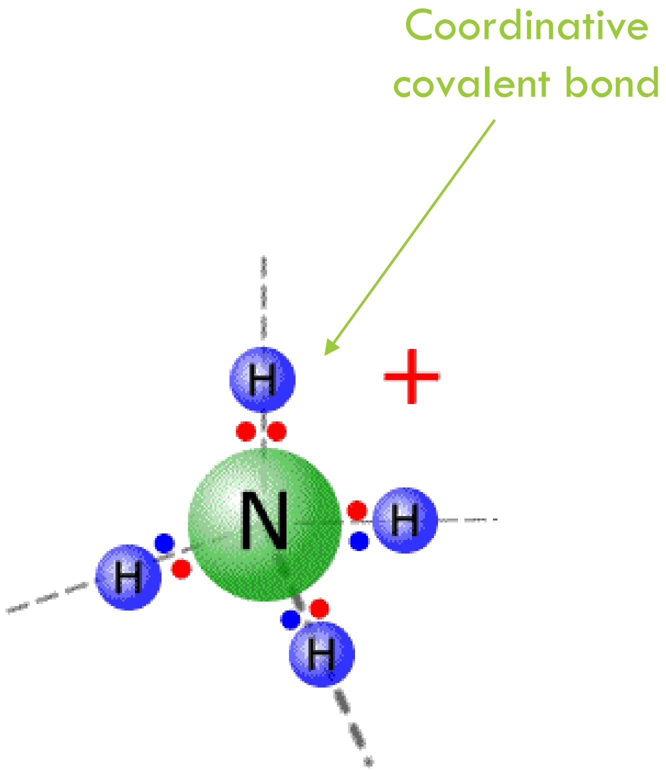
Ammonium NH_4^+ - Conjugate acid of ammonia (base)

$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

Reverse reaction:

Ammonia is the conjugate base of ammonium (acid)

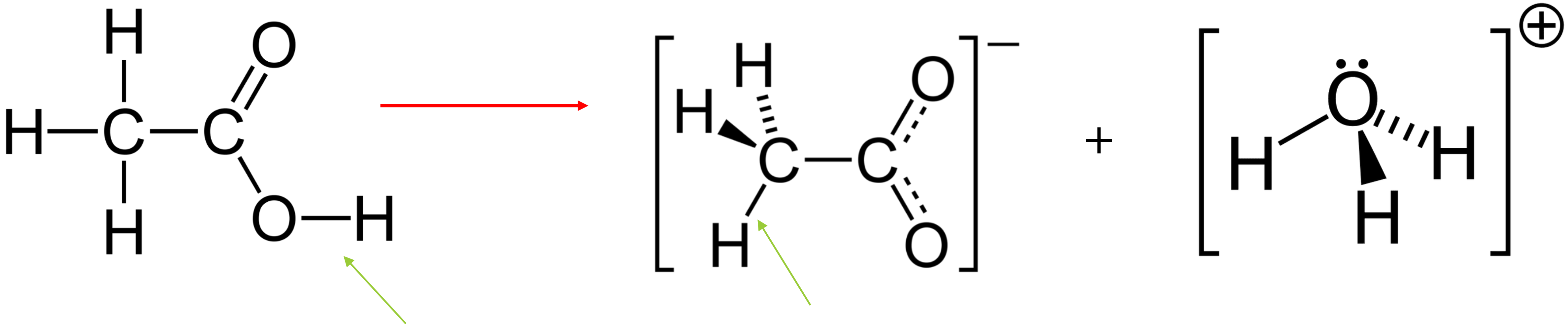
$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$



POSSIBLY CONFUSING MOLECULES

CH_3COONa

$CH_3COOH + H_2O \rightarrow CH_3COO^- + H_3O^+$



dipole

Covalent bonds

IS IT AN ACID OR A BASE?
(USE THE BRØNSTED-LOWRY DEFINITION)

Talk to the people around you to help decide your answers

- NH_3
- HBr
- SH^-
- H_2O

Q. IS IT AN ACID OR A BASE? (USE THE BRØNSTED-LOWRY DEFINITION)

- NH_3 Base – N is from group 15. Will accept a proton to form NH_4^+
- HBr Acid – Br is from group 17. HBr can loose a proton to form Br^-.
- SH^- Base – S is from group 16. Will accept a proton to form H_2S (and can be considered as deprotonated H_2S)
- H_2O Both! – O from group 16. The molecule is not deprotonated but can still act as a base. Can loose H^+ to form OH^-. Can accept H^+ to form H_3O^+

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What makes an acid/base ‘strong’ or ‘weak’?

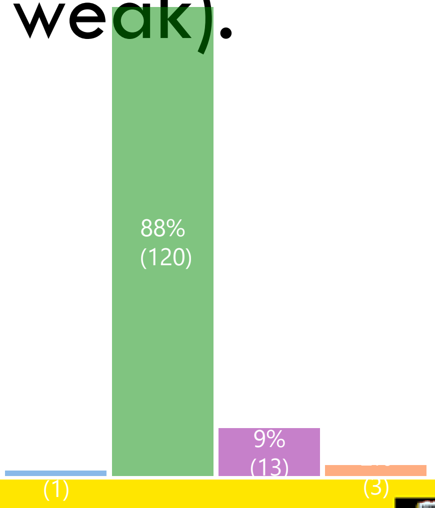
A How well it corrodes matter.

B The extent to which it ionises in water.

C The concentration of the solution.

D It’s a mystery yet to be solved by science.

E The size of the molecule (big: strong, small: weak).



STRONG ACIDS

- A strong acid is one that dissociates essentially completely to release H^+ ions in solution.

  – E.g. HCl, HBr, HI (but not HF), HNO_3, H_2SO_4, $HClO_3$, $HClO_4$

$$HCl\ (aq) \longrightarrow H^+\ (aq) + Cl^-\ (aq)$$

- A weak acid dissociates incompletely

STRONG BASES

A strong base is one that dissociates essentially completely (or reacts with water completely) to release OH^- ions in solution.

- E.g. $NaOH$, KOH, $Ba(OH)_2$

$$NaOH\,(s) + H_2O\,(l) \longrightarrow Na^+\,(aq) + OH^-\,(aq)$$

- A weak base reacts incompletely with water

Strong acids and bases are strong electrolytes, as their dissolved species exist as ions.

STRENGTH VS CONCENTRATION VS pH

- ✓The strength of an acid or base is a predetermined physical constant (i.e. can be looked up in a book)
- ✓The concentration of an acid or base is determinant on how it has been formulated and diluted (i.e. can be changed in a lab)
- ✓The pH of and acid or base is determined by both its strength and concentration.

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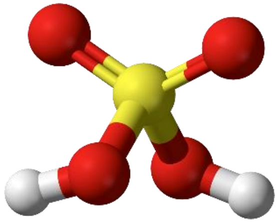
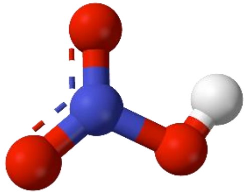
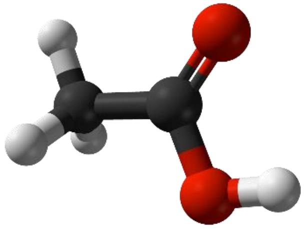
COMMON ACIDS



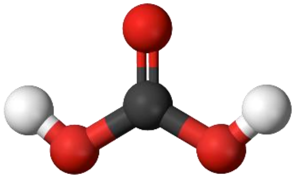
Sulfuric acid, H_2SO_4 – many industrial applications, e.g. making rubber



Nitric acid, HNO_3 – many industrial applications, e.g. making fertilizer



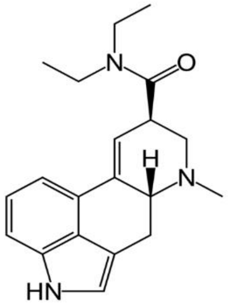
Acetic acid, CH_3CO_2H – present in vinegar

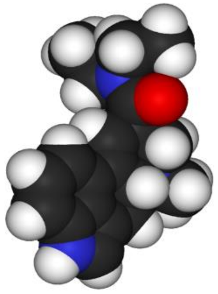


Carbonic acid, H_2CO_3 – results from CO_2 dissolved in water – fizzy drinks

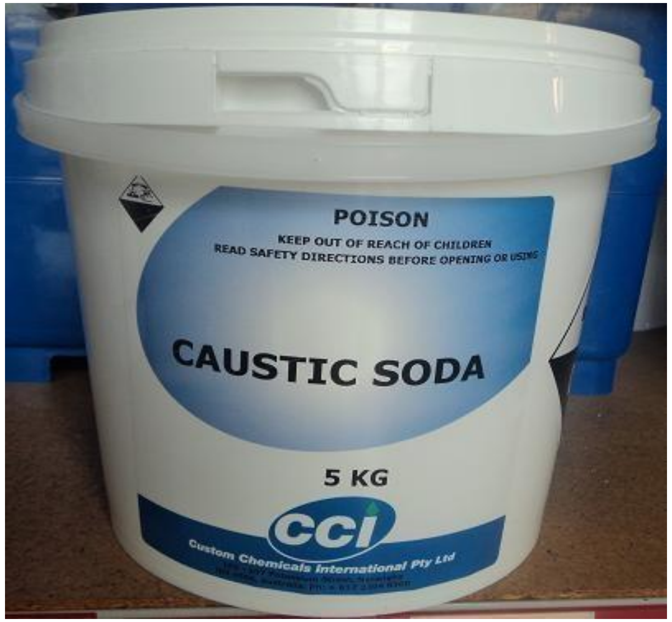
Lysergic acid diethylamide

- Not *that* sort of acid!!





COMMON BASES



Caustic soda – sodium hydroxide

Cleaning -Ammonia solution

Garden lime – mostly calcium carbonate

HOW DO I KNOW WHICH IS STRONG/WEAK ACID?!

Remember just the strong acids, as they are few.

Anything other acid (in first year chemistry!!) will be weak.

Not ~~HF~~

HCl HBr HI	HNO_3	H_2SO_4	$HClO_3$ $HBrO_3$ HIO_3	$HClO_4$ $HBrO_4$ HIO_4

HOW DO I KNOW WHICH IS STRONG/WEAK BASE?!

- A strong base reacts completely with water to give OH^- ions

Strong bases (for 1st year chem): group 1 and 2 metals and OH e.g.

- $LiOH$ – lithium hydroxide
- $NaOH$ – sodium hydroxide
- KOH – potassium hydroxide
- $Ca(OH)_2$ – calcium hydroxide

EXAMPLES OF WEAK ACIDS AND BASE

- A weak acid reacts only a small amount with water and forms relatively few H_3O^+ ions
- A weak base reacts only a small amount with water and forms relatively few OH^- ions

weak acids:

CH_3COOH – ethanoic acid
H_2CO_3 – carbonic acid
HF – hydrofluoric
H_3PO_4 – phosphoric acid

weak bases:

NH_3- ammonia
C_5H_5N – Pyridine
HCO_3^- - bicarbonate ion

MULTIPROTIC ACIDS

Some Brønsted acids can release more than one proton.

Monoprotic acids release one proton per molecule,

diprotic acids release two, and ***triprotic***, three.

For example:

Monoprotic hydrochloric acid: $HCl\ (aq) \longrightarrow H^+\ (aq) + Cl^-\ (aq)$

Diprotic sulfuric acid: $H_2SO_4\ (aq) \rightleftharpoons 2\ H^+\ (aq) + SO_4^{2-}\ (aq)$

Triprotic phosphoric acid: $H_3PO_4\ (aq) \rightleftharpoons 3\ H^+\ (aq) + PO_4^{3-}\ (aq)$

REACTIONS OF ACIDS

1. Neutralisation:

acid + base → salt + water

Example:

acid		base		salt		water

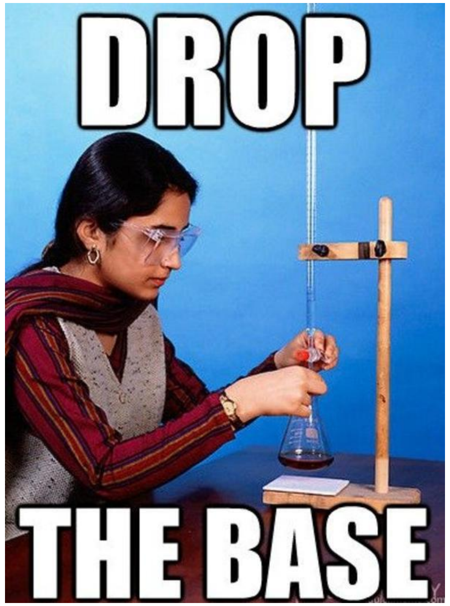
$$2HCl_{(aq)} + Mg(OH)_{2(aq)} \rightarrow MgCl_{2(aq)} + 2H_2O_{(l)}$$

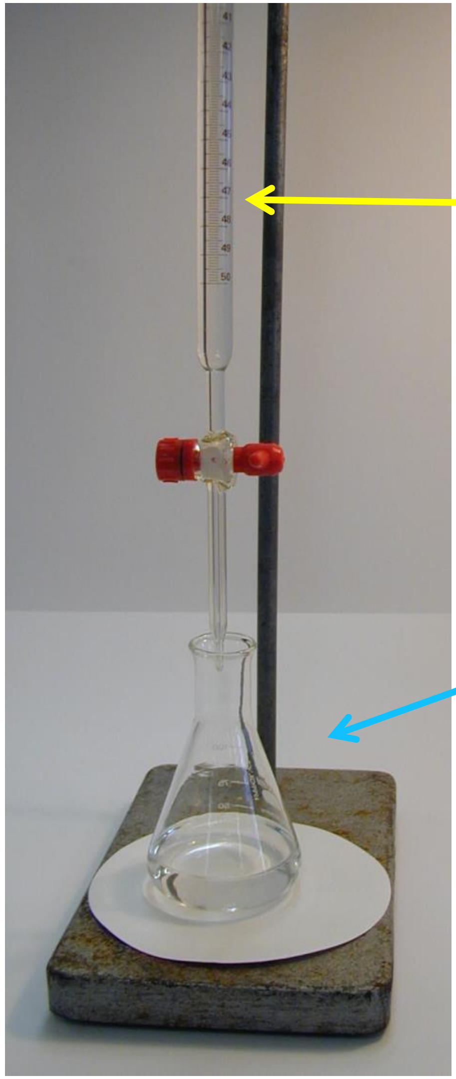
Ionic equation: $2H^+_{(aq)} + 2OH^-_{(aq)} \rightarrow 2H_2O_{(l)}$

Which simplifies to: $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(aq)}$

TITRATIONS

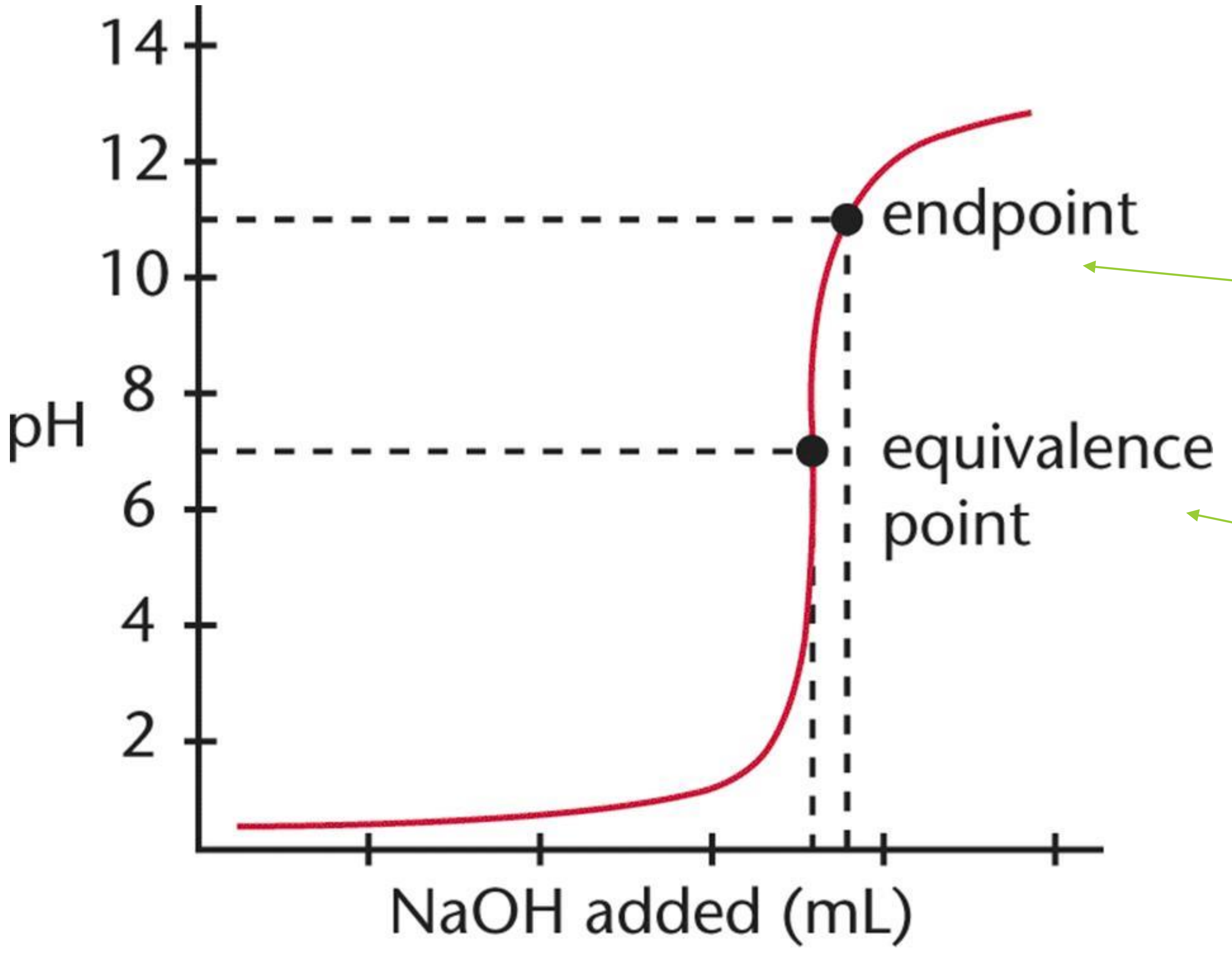
An analytical procedure in which a solute in a solution of known concentration reacts with a known stoichiometry with a substance whose concentration is to be determined.





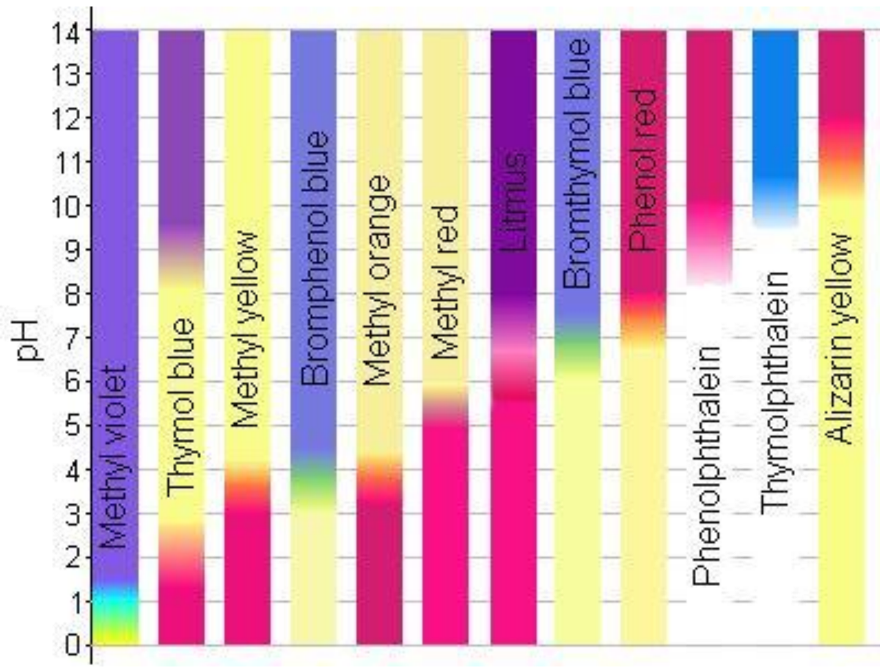
Burette (contains solution of known concentration)

Conical flask (contains solution of unknown concentration)



When a titration is stopped because a colour change in the indicator has been observed.

Exactly equal proportion of acid and base to achieve neutralisation.



TITRATION CALCULATIONS

Volume of known solution required (mean titre volume, in L)

↓ $n = c \times V$

moles of known solution (in mol)

↓ mole ratio

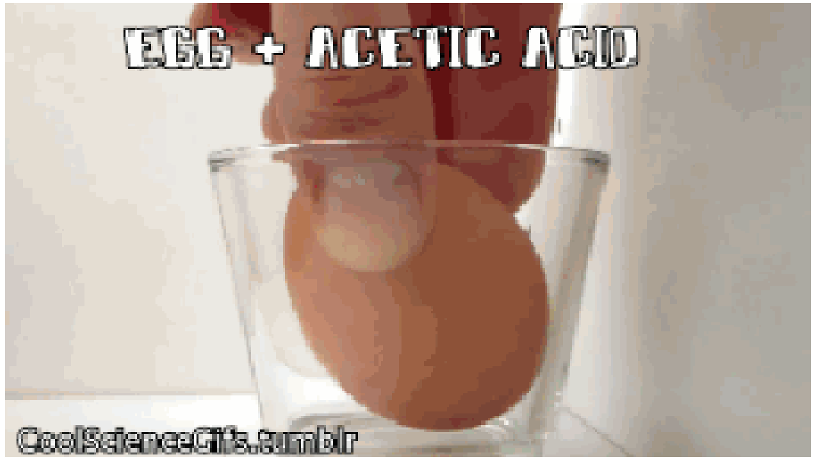
moles of unknown solution (in mol)

↓ $c = n/V$

Concentration of unknown solution

Remember that the volume of unknown solution is not the same as your known solution!

REACTIONS OF ACIDS



3. Reaction with carbonates:

acid + carbonate → salt + carbon dioxide gas + water

Example:

acid	carbonate		salt	carbon dioxide	water

$$2HCl_{(aq)} + CaCO_{3(s)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

Ionic equation: $2H^{+}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)}$

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REACTIONS OF ACIDS

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ACID RAIN AND LIMESTONE

Volkswagen: US judge approves $US14.7b settlement over diesel emissions cheating scandal

Posted 26 Oct 2016, 6:31am

A US federal judge has approved Volkswagen AG's record $US14.7 billion ($19.22 billion) settlement with regulators and owners of 475,000 polluting diesel vehicles, with the German automaker saying it would begin buying back the cars mid-November.

The action by US District Judge Charles Breyer in San Francisco marked a pivotal moment for VW as it aims to move past a scandal that has engulfed the company since it admitted in September 2015 to installing secret software in diesel cars to cheat exhaust emissions tests and make them appear cleaner than they really were.

PHOTO: The scandal rattled VW's global business and prompted the ouster of its CEO. (Reuters: Mike Blake, file)

- NOx emissions from cars and industry
- Sulfer – sulfite/sulfates from 'dirty' coal

REACTIONS OF ACIDS

2. Reaction with metals:

acid + metal → salt + hydrogen gas

Example:

acid | metal | salt | hydrogen gas

$$2HCl_{(aq)} + Mg_{(s)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

Ionic equation: $2H^{+}_{(aq)} + Mg_{(s)} \rightarrow Mg^{2+}_{(aq)} + H_{2(g)}$

HOMEWORK

Write ionic equations for the following reactions and determine the stoichiometric ratio of acid: base ;

1. HCl and Na_2CO_3
2. H_2SO_4 and Mg
3. H_3PO_4 and NaOH
4. $HClO_4$ and Zn