



# REDOX NO's

monatomic = its charge

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oxygen      in peroxides ( $H_2O_2$  etc.)

in compounds      -1

-2

# hydrogen in metal hydrides (NaH etc.)

## 1.1 - rate of chemical reactions

collision theory	<ul style="list-style-type: none"><li>- correct orientation<ul style="list-style-type: none"><li>- break the bonds of the reactants</li></ul></li><li>- sufficient energy<ul style="list-style-type: none"><li>- Maxwell-Boltzmann distribution curve (KE distribution diagram)</li><li>- activation energy</li></ul></li><li>- transition state<ul style="list-style-type: none"><li>&gt; highly energised, unstable</li></ul></li><li>- exothermic<ul style="list-style-type: none"><li>- <math>-\Delta H</math> (releases energy to surroundings)</li></ul></li><li>- endothermic<ul style="list-style-type: none"><li>- <math>+\Delta H</math></li></ul></li></ul>
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## 1.2 - factors that influence reaction rate

increasing collision frequency	<ul style="list-style-type: none"><li>- increase surface area<ul style="list-style-type: none"><li>- only surface react</li></ul></li><li>- increase concentration<ul style="list-style-type: none"><li>- more particles per unit of volume = higher freq. of collisions</li></ul></li><li>- increase gas pressure<ul style="list-style-type: none"><li>- increases number of gas particles in a given area</li></ul></li></ul>
partial pressure	the pressure of the individual gases in a mixture of gases are known as the partial pressures
increasing collision probability	<ul style="list-style-type: none"><li>- temperature<ul style="list-style-type: none"><li>- higher % of particles meet the activation energy</li></ul></li></ul> <ul style="list-style-type: none"><li>- the presence of catalysts<ul style="list-style-type: none"><li>- catalyst provides an alternative reaction pathway (lower Ea)</li><li>- greater proportion has sufficient energy</li></ul></li></ul>

## 2.1 - chemical systems

open and closed systems	<ul style="list-style-type: none"><li>- open system<ul style="list-style-type: none"><li>- both matter and energy can be exchanged with surroundings</li></ul></li><li>- closed system<ul style="list-style-type: none"><li>- can only exchange energy with surroundings</li></ul></li></ul>
reversible and irreversible systems	$\rightarrow$ is an irreversible reaction $\leftrightarrow$ is a reversible reaction
reversibility of physical and chemical changes	<ul style="list-style-type: none"><li>- evaporation and condensation of water<ul style="list-style-type: none"><li>- evaporation of water</li><li><math>H_2O(l) \longrightarrow H_2O(g)</math></li><li>- condensation of water</li><li><math>H_2O(g) \longrightarrow H_2O(l)</math></li><li>- therefore:</li></ul></li></ul> $H_2O(l) \rightleftharpoons H_2O(g)$

## 2.2 - dynamic equilibrium

- extent of reaction = how much product is formed when @ equilibrium

## 2.3 - equilibrium law

reaction quotient

equilibrium constant

- $K_c$  is different for different chemicals
- indicates the proportions of reactants and products in a mixture

expression for the equilibrium law

the equilibrium law states:  
-  $K_c$  is products/reactants

- doesn't include solids because they have a constant concentration

## 2.4 - working with equilibrium constants

	higher K <sub>c</sub> = more products than reactants lower K <sub>c</sub> = more reactants than products
the effect of temperature on equilibrium constant	exothermic reactions - K <sub>c</sub> decreases therefore amount of products decreases @ equilibrium endothermic reactions - K <sub>c</sub> increases therefore the amount of products increases @ equilibrium

## 2.5 - LCP

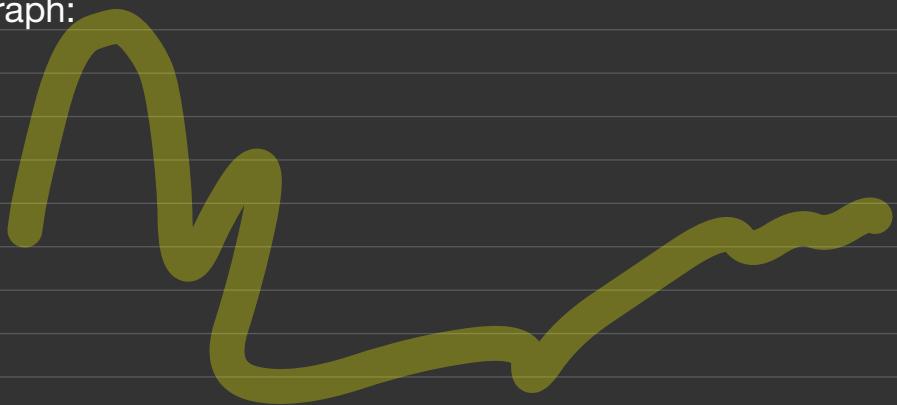
LeChatelier's Principle

adding extra reactant or product

LCP: shift to decrease concentration

collision theory: more particles = more collisions = shifts the other direction

graph:



## 2.6 - further applications of LCP

changing pressure  
by changing volume

LCP: produce less/more mols of gas  
collision theory: closer together = more reactions  
graph:



dilution

reduces the number of particles per volume  
- lowers the concentrations of everything  
graph:



changing temp.

$\Delta H$	$T$	$K_c$
Exothermic (-)	Increase	Decrease
Endothermic (+)	Increase	Increase

exothermic = decrease in  $K_c$   
endothermic = increase in  $K_c$

effect of a catalyst  
on equilibrium

- easier pathway  
graph:



## 4.1 - introduction to acids and bases

### properties of acids and bases

Properties of acids	Properties of bases
Turn litmus indicator red	Turn litmus indicator blue
Tend to be corrosive	Are caustic and feel slippery
Taste sour	Taste bitter
React with bases	React with acids
Solutions have a relatively low pH	Solutions have a relatively high pH
Solutions conduct an electric current	Solutions conduct an electric current

- acids dissociate (break apart) and ionise (form ions) in water
  - produce hydrogen ions ( $H^+$ )
- bases dissociate in water to form hydroxide ions ( $OH^-$ )

### brønsted-lowry

- acids are proton donors
- bases are proton acceptors

### advantages of brønsted-lowry

- allows ammonia to be identified as a base:
- $$HCl + NH_3 \rightarrow NH_4^+ + Cl^-$$

### limitations of brønsted-lowry

cannot be applied to the reaction between acidic and basic oxides

### conjugate acid-base pairs

$HCl + H_2O \rightarrow H_3O^+ + Cl^-$   
 $Cl^-$  is formed from  $HCl$  by losing a proton = conjugate base of  $HCl$   
 $HCl$  = conjugate acid of  $Cl^-$   
 $H_3O^+$  and  $H_2O$  are a conjugate pair too

### amphiprotic/amphoteric substances

monoprotic: one donate one proton per molecule  
 polyprotic: can donate more than one proton from each molecule

### diprotic

2 protons donated  
 $H_2SO_4$  and  $H_2CO_3$  are diprotic acids

### triprotic

3 protons donated  
 $H_3PO_4$  and  $H_3BO_3$  are triprotic acids

## 4.2 - strength of acids and bases

strong acids:

HCl

H<sub>2</sub>SO<sub>4</sub>

HNO<sub>3</sub>

weak acids:

CH<sub>3</sub>COOH

H<sub>2</sub>CO<sub>3</sub>

H<sub>3</sub>PO<sub>4</sub>

strong bases:

NaOH

KOH

Ca(OH)<sub>2</sub>

weak bases:

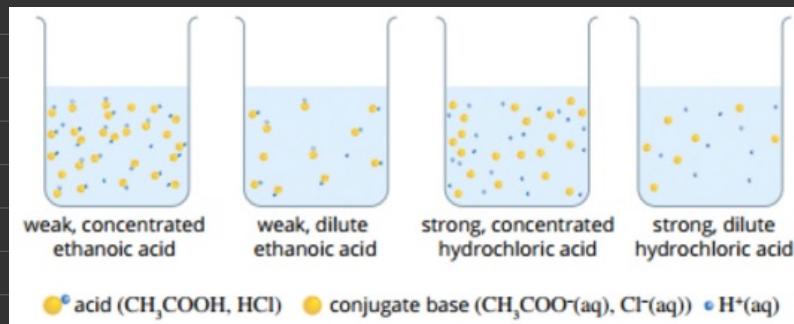
NH<sub>3</sub>

stronger = donate more protons (ionises more)

acid ionisation constants

$$K_a = [R]/[P]$$

strength vs concentration



## 4.3 - acidity of solutions



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

at 25 degrees C

neutral:  $[\text{H}_3\text{O}^+] = [\text{OH}^-] = 10^{-7}$

acidic:  $[\text{H}_3\text{O}^+] > 10^{-7}$  and  $[\text{OH}^-] < 10^{-7}$

basic:  $[\text{H}_3\text{O}^+] < 10^{-7}$  and  $[\text{OH}^-] > 10^{-7}$

**find the concentration of  $\text{H}_3\text{O}^+$**

HCl is completely ionised in water, 0.1 mol/L

$$[\text{H}_3\text{O}^+] = 0.1 \text{ mol/L}$$

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

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

since  $[\text{H}_3\text{O}^+] = 0.1 \text{ mol/L}$

$$[\text{OH}^-] = 1 \times 10^{-14}/0.1$$

$$= 1.0 \times 10^{-13} \text{ mol/L}$$

### definition of pH

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

$$[\text{H}_3\text{O}^+] = 10^{-\text{pH}}$$

neutral: 7

acidic: < 7

basic: > 7

calculate the pH of a solution where  $[\text{H}_3\text{O}^+] = 0.14 \text{ mol/L}$

$$= \log(0.14)$$

$$= 0.85$$

what is the pH of a 0.01 mol/L solution of  $\text{Ba}(\text{OH})_2$  at 25 degrees C?

What is the pH of a solution at 25°C that contains 1.0 g NaOH in 100 mL of solution?	
Thinking	Working
Determine the number of moles of NaOH.	$n(\text{NaOH}) = \frac{m}{M}$ $n(\text{NaOH}) = \frac{1.0}{40.0}$ $= 0.025 \text{ mol}$
Write the equation for dissociation of NaOH.	$\text{NaOH}(aq) \rightarrow \text{Na}^+(aq) + \text{OH}^-(aq)$ NaOH is completely dissociated in water.
Determine the number of moles of $\text{OH}^-$ based on the dissociation equation.	$n(\text{OH}^-) = n(\text{NaOH})$ $= 0.025 \text{ mol}$
Use the formula for determining concentration given number of moles and volume: $c = \frac{n}{V}$	$n = 0.025 \text{ mol}$ $V = 0.100 \text{ L}$ $c = \frac{0.025}{0.100} = 0.25 \text{ mol L}^{-1}$
Determine $[\text{H}_3\text{O}^+]$ in the diluted solution by substituting $[\text{OH}^-]$ into the ionic product of water: $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1.00 \times 10^{-14}$	$K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1.00 \times 10^{-14}$ $[\text{H}_3\text{O}^+] = \frac{K_w}{[\text{OH}^-]}$ $= \frac{1.00 \times 10^{-14}}{0.25}$ $= 4.0 \times 10^{-14} \text{ mol L}^{-1}$
Substitute the value of $[\text{H}_3\text{O}^+]$ into: $\text{pH} = -\log_{10}[\text{H}_3\text{O}^+]$ Use the logarithm function on your calculator to determine the answer.	$\text{pH} = -\log_{10}[4.0 \times 10^{-14}]$ (use your calculator) $= 13.4$

## effect of temperature on pH

Temperature (°C)	$K_w$	pH
0	$1.14 \times 10^{-15}$	7.47
5	$1.85 \times 10^{-15}$	7.37
15	$4.51 \times 10^{-15}$	7.17
25	$1.00 \times 10^{-14}$	7.00
35	$2.09 \times 10^{-14}$	6.83
45	$4.01 \times 10^{-14}$	6.70
55	$7.29 \times 10^{-14}$	6.57

## 4.4 - dilution of acids and bases

concentration of acids and bases

$$c = n/V$$

$$c_1V_1 = c_2V_2$$

### calculating molar concentration after dilution

Calculate the molar concentration of hydrochloric acid when 10.0mL of water is added to 5.0mL of  $1.2\text{ mol L}^{-1}$  HCl.

Thinking	Working
<p>The number of moles of solute does not change during a dilution. So, <math>c_1V_1 = c_2V_2</math>, where <math>c</math> is the concentration in <math>\text{mol L}^{-1}</math> and <math>V</math> is the volume of the solution. (Each of the volume units must be the same, litres or millilitres.)</p>	$c_1V_1 = c_2V_2$
<p>Identify given values for concentrations and volumes before and after dilution. Identify the unknown.</p>	<p>10.0mL was added to 5.0mL, the final volume is 15.0mL. <math>c_1 = 1.2\text{ mol L}^{-1}</math> <math>V_1 = 5.0\text{ mL}</math> <math>V_2 = 15.0\text{ mL}</math> You are required to calculate <math>c_2</math>, the concentration after dilution.</p>
<p>Transpose the equation and substitute the known values into the equation to find the required value.</p>	$\begin{aligned}c_2 &= \frac{c_1 \times V_1}{V_2} \\&= 1.2 \times \frac{5.0}{15.0} \\&= 0.40\text{ mol L}^{-1}\end{aligned}$

### calculating molar concentration after dilution

How much water must be added to 30.0mL of  $2.50\text{ mol L}^{-1}$  HCl to dilute the solution to  $1.00\text{ mol L}^{-1}$ ?

Thinking	Working
<p>The number of moles of solute does not change during a dilution. So, <math>c_1V_1 = c_2V_2</math>, where <math>c</math> is the concentration in <math>\text{mol L}^{-1}</math> and <math>V</math> is the volume of the solution. (Each of the volume units must be the same, although not necessarily litres.)</p>	$c_1V_1 = c_2V_2$
<p>Identify given values for concentrations and volumes before and after dilution. Identify the unknown.</p>	$\begin{aligned}c_1 &= 2.50\text{ mol L}^{-1} \\V_1 &= 30.0\text{ mL} \\c_2 &= 1.00\text{ mol L}^{-1}\end{aligned}$ <p>You are required to calculate <math>V_2</math>, the volume of the diluted solution.</p>

Transpose the equation and substitute the known values into the equation to find the required value.	$\begin{aligned}V_2 &= \frac{c_1 \times V_1}{c_2} \\&= \frac{2.50 \times 30.0}{1.00} \\&= 75.0\text{ mL}\end{aligned}$
Calculate the volume of water to be added.	<p>Volume of dilute solution = 75.0mL Initial volume of acid = 30.0mL So <math>75.0 - 30.0 = 45.0\text{ mL}</math> of water must be added.</p>

## calculating pH of a diluted acid

5.0mL of 0.010molL<sup>-1</sup> HNO<sub>3</sub> is diluted to 100.0mL. What is the pH of the diluted solution?

Thinking	Working
Identify given values for concentrations and volumes before and after dilution.	$c_1 = 0.010\text{ mol L}^{-1}$ $V_1 = 5.0\text{ mL}$ $V_2 = 100.0\text{ mL}$ $c_2 = ?$
Calculate $c_2$ , which is the concentration of H <sub>3</sub> O <sup>+</sup> after dilution, by transposing the formula: $c_1 V_1 = c_2 V_2$	$c_2 = \frac{c_1 \times V_1}{V_2}$ $= \frac{0.010 \times 5.0}{100.0}$ $= 0.00050\text{ mol L}^{-1}$
Calculate pH using: $\text{pH} = -\log_{10}[\text{H}_3\text{O}^+]$ Use the logarithm function on your calculator to determine pH.	$\text{pH} = -\log_{10}[\text{H}_3\text{O}^+]$ $= -\log_{10}(0.00050)$ $= 3.30$

1. calculate [OH<sup>-</sup>] in the diluted solution
2. calculate [H<sub>3</sub>O<sup>+</sup>], using the expression for the ionic product of water:  
 $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}$
3. calculate pH of solution using  $\text{pH} = -\log[\text{H}_3\text{O}^+]$

## 4.5 - pH of salt solutions

salts	<u>salt</u> : ionic compound that contains a positive ion (a cation) other than a hydrogen ion ( $H^+$ ) or a negative ion (an anion) other than the oxide ion ( $O^{2-}$ ) or the hydroxide ion ( $OH^-$ )
salt solutions from neutralisation reactions	from the reaction between an acid and a base $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$
salts of s.a and s.b	neutral salt
salts of s.a and w.b	acidic salt
salts of w.a and s.b	basic salt
salts of w.a and w.b	depends on extent of hydrolysis of each ion
hydrolysis of salts and polyprotic acids	hydrolysis of sodium carbonate $\begin{aligned} HCO_3^-(aq) + H_2O(l) &\rightleftharpoons H_2CO_3(aq) + OH^-(aq) \\ HCO_3^-(aq) + H_2O(l) &\rightleftharpoons CO_3^{2-}(aq) + H_3O^+(aq) \end{aligned}$ the first reaction occurs to a greater extent than the second reaction so the sodium hydrogencarbonate solution is basic
<p>Sodium hydrogensulfate (<math>NaHSO_4</math>) is a salt of sulfuric acid and forms an acidic solution in water because the following reaction dominates:</p> $HSO_4^-(aq) + H_2O(l) \rightleftharpoons SO_4^{2-}(aq) + H_3O^+(aq)$	
<p>Sodium phosphate (<math>Na_3PO_4</math>) sodium hydrogenphosphate (<math>Na_2HPO_4</math>) and sodium dihydrogenphosphate (<math>NaH_2PO_4</math>) are all salts of phosphoric acid.  Sodium dihydrogenphosphate dissolves in water forming an acidic solution:  <math display="block">H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons HPO_4^{2-}(aq) + H_3O^+(aq)</math>  Solutions of sodium dihydrogenphosphate and sodium phosphate in water are basic:  <math display="block">\begin{aligned} HPO_4^{2-}(aq) + H_2O(l) &amp;\rightleftharpoons H_2PO_4^-(aq) + OH^-(aq) \\ PO_4^{3-}(aq) + H_2O(l) &amp;\rightleftharpoons HPO_4^{2-}(aq) + OH^-(aq) \end{aligned}</math></p>	

## 5.1 - introducing buffers

- able to resist changes in pH when small amounts of acid or base are added
- important for processes that require stable and narrow pH ranges

buffer consists of: conjugate acid-base pair

- weak acid + its conjugate base
- weak base + its conjugate acid



## 5.2 - how buffers work

adding acid to a buffer	initial equilibrium $\text{HA} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{A}^-$ (addition of acid) buffer re-establishes equilibrium, maintaining a stable pH $\text{HA} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{A}^-$ (reverse is favoured)
adding base to a buffer	$\text{HA} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{A}^-$ $[\text{H}_3\text{O}^+]$ stays approximately constant $\text{HA(aq)}$ combined with any $\text{OH}^-$ that is added $\text{A}^-(\text{aq})$ combines with any $\text{H}_3\text{O}^+$ that is added  $\text{HA}$ is weak acid $\text{A}^-$ = conjugate base
buffer capacity	the more $\text{A}^-$ and $\text{HA}$ molecules available, the less of an effect adding a strong acid or base will have on the pH of a system  <u>buffer capacity</u> : the measure of the effectiveness of a buffer solution at resisting a change in pH when either a strong acid or a strong base is added  it is greatest when: - there is a high [ ] of weak acid and its conjugate base - the [ ]s of the acid and its conjugate base are equal

## 6.1 - characteristics of indicators

properties of indicators	$\text{HIn(aq)} + \text{H}_2\text{O(l)} \rightleftharpoons \text{In-(aq)} + \text{H}_3\text{O}^+(\text{aq})$
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## 6.2 - common indicators

universal indicator      red -> yellow -> green -> blue -> purple

bromothymol blue      yellow -> green -> blue  
0-6 -> 7 -> 8-14

methyl orange      red -> yellow  
0-4 -> 5-14

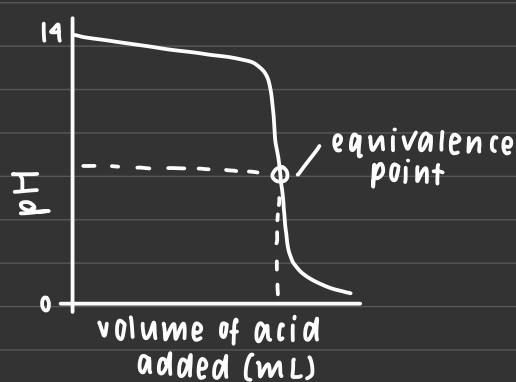
phenolphthalein      colourless -> pink  
0-8.5 -> 8.5-14

## 6.3 - pH range of an indicator

Indicator	Colour in acidic solution	Colour in basic solution	pH range
Methyl violet	Yellow	Violet	0.0–1.6
Methyl orange	Red	Yellow	3.1–4.4
Methyl red	Red	Yellow	4.4–6.2
Bromothymol blue	Yellow	Blue	6.0–7.6
Phenolphthalein	Colourless	Pink	8.3–10.0
Alizarin yellow	Yellow	Red	10.0–12.0

using indicators

helpful for determining the equivalence point of a neutralisation reaction between an acid and a base  
 - equivalence point = around of acid and base are in the stoichiometric ratio  
titration curve/pH curve:

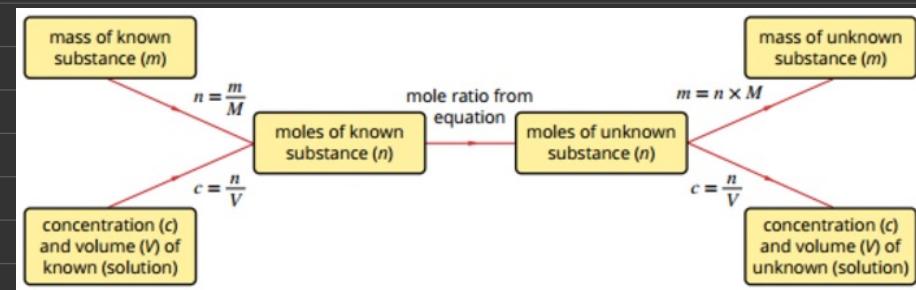


## 7.1 - acids and bases in water

pH of rainwater	carbon dioxide dissolves in rain, forming a very dilute solution of carbonic acid ( $\text{H}_2\text{CO}_3$ ) $\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{HCO}_3^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
acid rain	sulfur dioxide gas is the main cause of acid rain $\text{S}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{SO}_2(\text{g})$ $\text{SO}_2(\text{g}) \rightarrow \text{SO}_3(\text{g}) \rightarrow \text{H}_2\text{SO}_4 \text{ (in rain)}$

## 7.2 - calculations involving acids and bases

- |   |   |
|---|---|
| reacting quantities<br>of acids and bases | <ol style="list-style-type: none"><li>1. balanced equation</li><li>2. identify known substance (usually known volume and concentration) to calculate number of mols</li><li>3. use mole ratio from equation to calculate the amount in mol of unknown substance</li><li>4. calculate the volume or concentration from the number of moles</li></ol> |
|---|---|



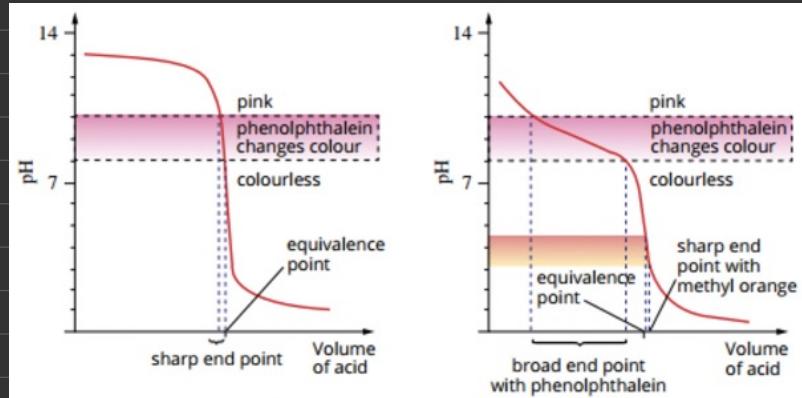
## 7.3 - standard solutions

primary standards	<p><u>primary standards</u>: substances that are so pure that the amount of substance, in moles, can be calculated accurately from their mass</p> <p>amount in mol(<math>n</math>) = mass of solute(in g)/molar mass(in g/mol) = <math>m/M</math> concentration(<math>C</math>) = amount of solute(in mol)/volume of solution(in L) = <math>n/V</math> <math>= m/MV</math></p>
concentration of standard solutions	<p>use the chemical formula of the primary standard to determine the molar mass of the compound</p> <p>use the mass and molar mass of the primary standard to determine the amount, in moles, dissolved in the volumetric flask</p> <p>use the amount, in moles, of the primary standard and the volume of the flask to determine the concentration of the standard solution</p>

## 7.4 - volumetric analysis

acid-base titrations | volumetric equipment  
the solution is slowly titrated until the indicator changes colour  
= equivalence point

pH change during a titration | equivalence point = when the curve is the steepest



## 7.5 - calculations in volumetric analysis

titrations	<ol style="list-style-type: none"> <li>1. balanced equation</li> <li>2. volume of the average titre</li> <li>3. use [ ] of standard solution to calculate the amount, in moles, of primary standard in the average titre</li> <li>4. use the mole ratio in the equation to calculate the amount, in moles, of the unknown</li> <li>5. amount, in moles that reacted with the sample volume to determine the [ ] of the unknown</li> </ol>
titrations involving dilutions	<ol style="list-style-type: none"> <li>1. balanced equation</li> <li>2. [ ] of standard to calculate the amount in moles of the primary standard that reacted</li> <li>3. use mole ratio in the equation to determine the amount, in moles, of diluted unknown substance that reacted in the titration</li> <li>4. determine [ ] of diluted unknown substance</li> <li>5. multiply [ ] of diluted by dilution factor to determine the [ ] of undiluted unknown substance</li> </ol>
back titrations	<p>dilution factor = initial volume/volume of aliquot</p> <p>used to determine the amount of acid or base for situations where: some acids or bases don't lend to normal titration</p> <pre> graph TD     A[n(NaOH) supplied] -- "-" --&gt; B[n(NaOH) remaining]     B --&gt; C[n(NaOH) reacting with NH4+]     C --&gt; D[m(NH4+) in sample]     D --&gt; E[% (NH4+) in sample]   </pre>

## BACK TITRATION

A student was asked to determine the concentration of ammonia in cloudy ammonia solution used for cleaning. First she pipetted 20.00 mL of the cloudy ammonia solution into a 250.0 mL conical flask.

She then added 50.00 mL of 0.100 mol L<sup>-1</sup> HCl(aq) to the conical flask to react with the ammonia in solution. The resultant mixture of excess, unreacted HCl was then titrated with 0.050 mol L<sup>-1</sup> Na<sub>2</sub>CO<sub>3</sub>(aq). A volume of 20.50 mL of Na<sub>2</sub>CO<sub>3</sub>(aq) was required.

Calculate the concentration of the ammonia in the cloudy ammonia solution.

**Step 1: From the titration results determine the amount of HCl in excess. This is the HCl that is left over after all the ammonia is used up in the first step.**

Thinking	Working
Write the equation for the titration.	$2\text{HCl}(\text{aq}) + \text{Na}_2\text{CO}_3(\text{aq}) \rightarrow 2\text{NaCl}(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
Calculate the moles, $n$ , of Na <sub>2</sub> CO <sub>3</sub> (aq) that reacted in the titration: $\text{moles} = \text{concentration } (\text{mol L}^{-1}) \times \text{volume (L)}$	$n(\text{Na}_2\text{CO}_3) = c \times V$ $c(\text{Na}_2\text{CO}_3) = 0.050 \text{ mol L}^{-1}$ $V(\text{Na}_2\text{CO}_3) = 20.50 \text{ mL} = 0.02050 \text{ L}$ $n(\text{Na}_2\text{CO}_3) = 0.050 \times 0.02050 = 0.001025 \text{ mol}$
Use the balanced chemical reaction for the titration to determine the moles of excess HCl that reacted in the titration.	From the balanced chemical equation, 1 mole Na <sub>2</sub> CO <sub>3</sub> reacts with 2 moles of HCl So, 0.001025 mol Na <sub>2</sub> CO <sub>3</sub> reacted with $2 \times 0.001025 \text{ mol HCl}$ $n(\text{HCl})_{\text{excess}} = 0.001025 \text{ mol} = 0.002050 \text{ mol}$
<b>Step 2: Determine the amount of ammonia in the cloudy ammonia solution</b>	
Calculate the total moles of HCl originally added to the diluted cloudy ammonia solution: $\text{moles} = \text{concentration } (\text{mol L}^{-1}) \times \text{volume (L)}$	$n(\text{HCl}) = c \times V$ $c(\text{HCl}) = 0.100 \text{ mol L}^{-1}$ $V(\text{HCl}) = 50.00 \text{ mL} = 0.05000 \text{ L}$ $n(\text{HCl})_{\text{total added}} = 0.100 \times 0.05000 = 0.00500 \text{ mol}$
Calculate the moles of HCl that reacted with the ammonia in the diluted cloudy ammonia solution by taking away the amount in excess from the total amount.	$n(\text{HCl})_{\text{titrated}} + n(\text{HCl})_{\text{reacted with ammonia}} = n(\text{HCl})_{\text{total added}}$ $n(\text{HCl})_{\text{total added}} = 0.00500 \text{ mol}$ $n(\text{HCl})_{\text{titrated}} = 0.002050 \text{ mol} \text{ (calculated in Step 1)}$ $n(\text{HCl})_{\text{reacted with ammonia}} = n(\text{HCl})_{\text{total added}} - n(\text{HCl})_{\text{titrated}}$ $n(\text{HCl})_{\text{reacted with ammonia}} = 0.00500 - 0.002050 = 0.00295 \text{ mol}$
Write the balanced chemical equation for the reaction between ammonia in the cloudy ammonia solution and the HCl(aq).	$\text{NH}_3(\text{aq}) + \text{HCl}(\text{aq}) \rightarrow \text{NH}_4^+\text{Cl}(\text{aq})$
From the balanced chemical equation, calculate the number of moles of NH <sub>3</sub> that reacted with HCl.	From the equation, 1 mol HCl reacts with 1 mol NH <sub>3</sub> $n(\text{NH}_3) = (1/1) \times n(\text{HCl})$ $= 0.00295 \text{ mol}$
Calculate the ammonia concentration in the cloudy ammonia solution. $\text{concentration } (\text{mol L}^{-1}) = \frac{n}{V}$ $= \text{moles/volume (L)}$	$c(\text{NH}_3) = \frac{n}{V}$ $n(\text{NH}_3) = 0.00295 \text{ mol} \text{ (moles of NH}_3 \text{ that reacted with HCl)}$ $V(\text{NH}_3) = 20.00 \text{ mL} = 0.02000 \text{ L} \text{ (volume of ammonia solution that reacted with HCl)}$ $c(\text{NH}_3) = \frac{0.00295}{0.02000} = 0.1475 \text{ mol L}^{-1}$
State the concentration of ammonia in the cloudy ammonia solution to the correct number of significant figures.	$c(\text{NH}_3) \text{ in the cloudy ammonia} = 0.147 \text{ mol L}^{-1}$

precision vs accuracy	<p><u>precise:</u> values in close agreement</p> <p><u>accurate:</u> very close to the accepted value</p>									
types of errors	<p><u>systematic:</u> cannot be eliminated by repeating the measurement e.g.  <ul style="list-style-type: none"> <li>- faulty balance</li> <li>- 20mL pipette that delivers 20.2mL</li> <li>- bad indicator</li> <li>- person reading the burette wrong</li> </ul> </p> <p><u>random:</u> follow no regular pattern too large or too small e.g.  <ul style="list-style-type: none"> <li>- difficulty judging where the meniscus sits on the line</li> <li>- difficulty judging between the fraction between markings on the burette</li> </ul> </p> <p><u>mistakes:</u> e.g.  <ul style="list-style-type: none"> <li>- misreading numbers on a scale</li> <li>- using a pipette of the wrong volume</li> <li>- spilling some of the sample</li> </ul> </p>									
rinsing	<table border="1"> <thead> <tr> <th></th> <th>Correct</th> <th>Incorrect</th> </tr> </thead> <tbody> <tr> <td>Burette Pipette</td> <td>The final rinse should be with the acid or base they are to be filled with.</td> <td>Rinsing with water only would dilute the acid or base solution.</td> </tr> <tr> <td>Volumetric flask Titration flask (conical flask)</td> <td>Should only be rinsed with deionised water.</td> <td>Rinsing with acidic or basic solutions will introduce unmeasured amounts of acids or bases into the flask, which can react and affect the results.</td> </tr> </tbody> </table>		Correct	Incorrect	Burette Pipette	The final rinse should be with the acid or base they are to be filled with.	Rinsing with water only would dilute the acid or base solution.	Volumetric flask Titration flask (conical flask)	Should only be rinsed with deionised water.	Rinsing with acidic or basic solutions will introduce unmeasured amounts of acids or bases into the flask, which can react and affect the results.
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## 8.1 - oxidation and reduction

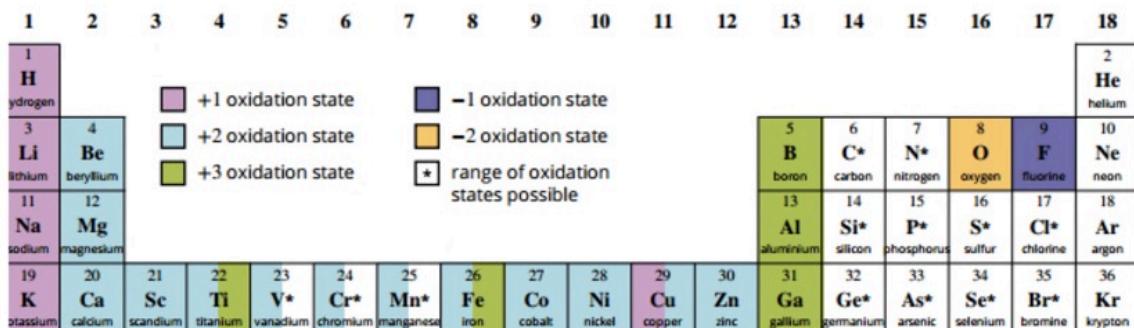
	oxidation and reduction occur simultaneously
	L E O, G E R losing electrons oxidation, gaining electrons reduction
	or
	O I L, R I G oxidation is losing, reduction is gaining
oxidising/reducing agents	oxidising agent is reduced (cause another chemical to be oxidised) reducing agent is oxidised (cause another chemical to be reduced)
overall redox equation	x sides by other electrons

## 8.2 - oxidation numbers

### oxidation numbers rules

**TABLE 8.2.1** Rules for determining oxidation numbers of elements in compounds

Rule	Examples
1 The oxidation number of a free (uncombined) element is zero.	$\text{Na}^0, \text{C}^0, \text{Cl}_2^0, \text{P}_4^0$
2 The oxidation number of a simple ion is equal to the charge on the ion.	$\text{Na}^{+1}, \text{Cl}^{-1}, \text{Mg}^{2+}, \text{O}^{2-}, \text{Al}^{3+}, \text{N}^{3-}$
3 In compounds, some elements have oxidation numbers that are regarded as fixed, except in a few exceptional circumstances.	
a Main group metals have an oxidation number equal to the charge on their ions.	Ionic compounds: $\text{K}^{+1}\text{Cl}^{-1}, \text{Mg}^{+2}\text{SO}_4^{-2}$
b Hydrogen has an oxidation number of +1 when it forms compounds with non-metals. Exception: In metal hydrides, the oxidation number of hydrogen is -1.	Compounds of H: $\text{H}^{+1}\text{O}^{-2}$ Metal hydrides: $\text{Na}^{-1}\text{H}, \text{Ca}^{-1}\text{H}_2$
c Oxygen usually has an oxidation number of -2. Exceptions: In compounds with fluorine, oxygen has a positive oxidation number (because fluorine is more electronegative than oxygen—see rule 6). In peroxides, oxygen has an oxidation number of -1.	Compounds of O: $\text{H}_2\overset{-2}{\text{O}}$ Peroxides: $\text{H}_2\overset{-1}{\text{O}}_2, \text{Ba}\overset{-1}{\text{O}}_2$
4 The sum of the oxidation numbers in a neutral compound is zero.	$\text{CO}_2^{+4-2}$
5 The sum of the oxidation numbers in a polyatomic ion is equal to the charge on the ion.	$\text{SO}_4^{+6-2}, \text{NH}_4^{+3-1}$
6 The most electronegative element is assigned the negative oxidation number.	$\text{OF}_2^{+2-1}$



**FIGURE 8.2.2** Part of the periodic table showing the most common oxidation states of some elements

increase in oxidation number = oxidised  
decrease in oxidation number = reduced

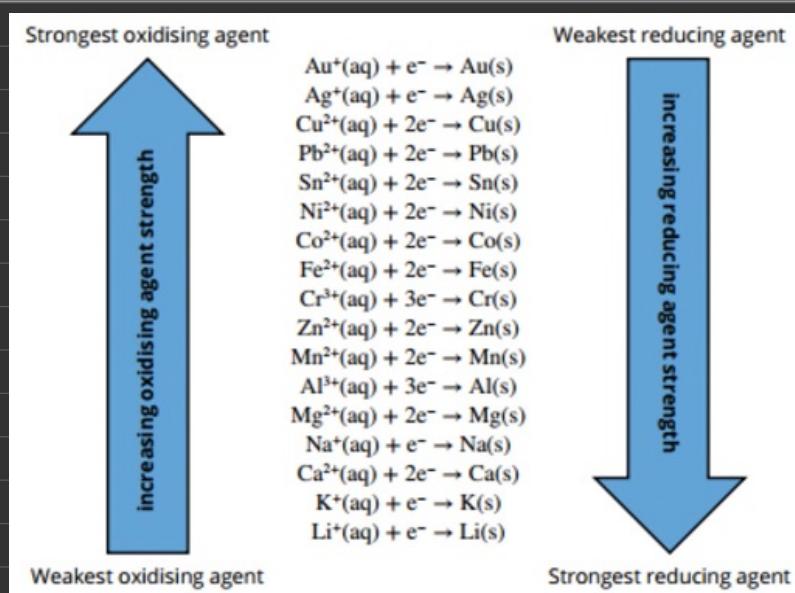
### 8.3 - more complex redox equations

balancing O and H  
in half-equations

1. balance all but O and H
2. balance O by adding H<sub>2</sub>O
3. balance H by adding H<sup>+</sup> ions
4. balance the charge with electrons
5. add state symbols

^ only for acidic conditions

## 8.4 - reactivity series of metals

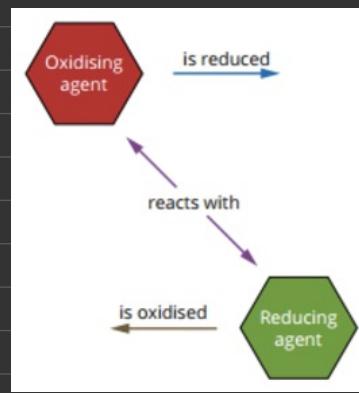


- metals on the right hand side become more reactive
  - the metals lower in the series are easier to oxidise and therefore are stronger reducing agents
- metal cations on the left hand side become increasingly harder to reduce and therefore are less reactive
  - cations higher in the series have a greater attraction for electrons so they are easier to reduce and are therefore relatively strong oxidising agents

metal displacement reactions

a more reactive metal will be oxidised by the less reactive metal, donating its electrons to it  
 cation receives electrons is reduced  
 - spontaneous redox reaction occurs

i.e. higher metal ion reacts with a lower metal ion

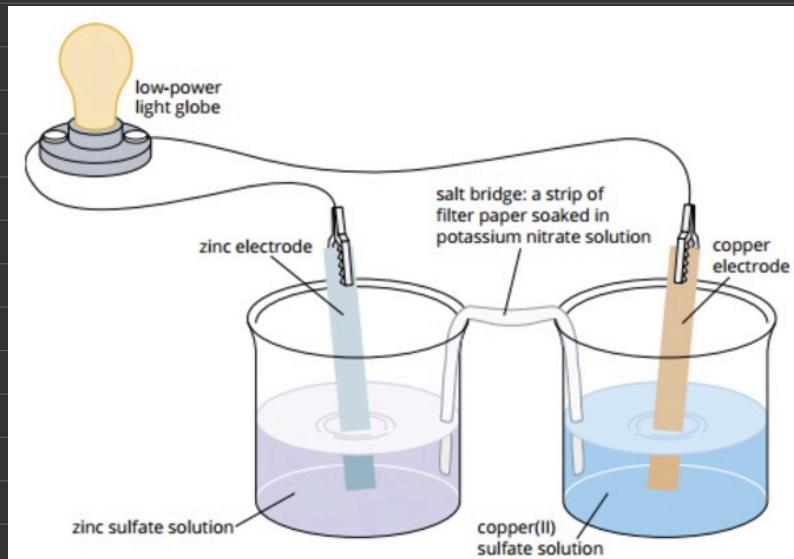


## 9.1 - galvanic cells

chemical energy  $\rightarrow$  electrical energy

connect more electrochemical cells together = battery

electrical circuit



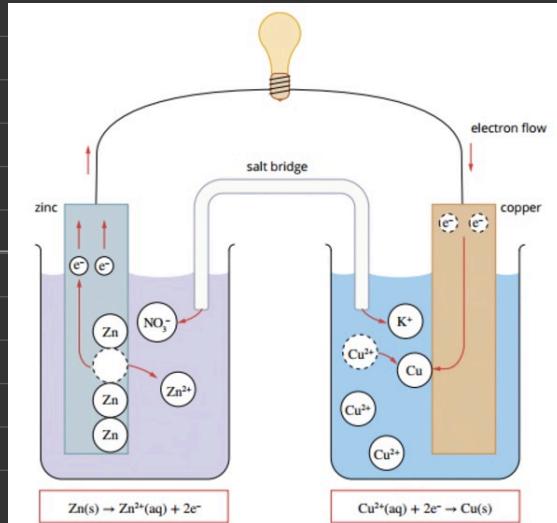
- zinc corrodes
- copper metal becomes covered in dark brown deposit
- copper(II) solution loses some of its colour

electrons flow from Zn  $\rightarrow$  Cu

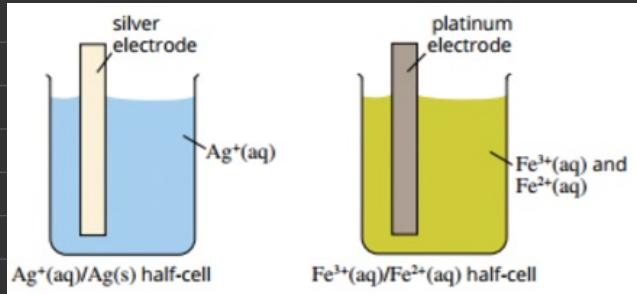
salt bridge is soaked with unreactive electrolyte  
- KNO<sub>3</sub> (doesn't form precipitates with either solution)

### observations:

- zinc electrode corrodes because Zn  $\rightarrow$  Zn<sup>2+</sup> ions in solution
- oxidation of Zn metals releases electrons, flow through the wire to the Cu electrode
- electrons accepted by copper(II)
- Cu<sup>2+</sup>  $\rightarrow$  Cu(s)
- copper metal formed deposits on the electrode



## half cells



oxidation - anode (electrons lost)  
reduction - cathode (electrons gained)

## purpose of the salt bridge

cations in the salt bridge move towards the cathode and anions in the salt bridge move towards the anode  
- without it, the negative and positive charges would accumulate and stop the reaction very quickly

also called the internal circuit

## flow

electrons flow from anode  $\rightarrow$  cathode

## relative oxidising and reducing strengths

	<p>because electrons from Zn<sup>2+</sup>/Zn half cell to the H<sup>+</sup>/H<sub>2</sub> half cell:</p> <ul style="list-style-type: none"><li>- Zn is a stronger reducing agent than H<sub>2</sub></li><li>- H<sup>+</sup> is a stronger oxidising agent than Zn<sup>2+</sup> ions</li></ul>
potential difference	<p>standard electrode potentials E<sub>0</sub> value</p>

## 11.1 - yield and chemical industry

theoretical and actual yields	<p>theoretical yield = all reactants <math>\rightarrow</math> products</p> <ul style="list-style-type: none"><li>- calculated using mole ratios of the equation</li><li>- max amount of product that can be formed using stoichiometric ratios of the reactants and assumes 100% conversion</li></ul>
	actual yield = reaches equilibrium rather than continuing to completion
% yield	$\% \text{ yield} = \frac{\text{actual yield}}{\text{theoretic yield}} \times 100$
quantities of gases in reactions	<p>@ STP (273.15K, 100kPa, mols of gas, <math>n=V/22.4</math>)</p> <p>it is unlikely that a reaction will be carried out at STP therefore, use the ideal gas law: <math>PV=nRT</math></p> <p>P = gas pressure in kPa</p> <p>V = gas volume in L</p> <p>n = mols</p> <p>R = 8.314J/Kmol (universal gas constant)</p> <p>T = temp in Kelvin</p>

## 11.2 - calculations involving limiting reagents

- both reactants aren't completely used - one runs out first
- one reactant is in excess (excess reagent)
- one reactant runs out (limiting reagent)
  - this is completely used up



4 molecules H<sub>2</sub> + 2 molecules of O<sub>2</sub> → 4 molecules of H<sub>2</sub>O

4 molecules H<sub>2</sub> + 4 molecules of O<sub>2</sub> → 4 molecules of H<sub>2</sub>O + 2 molecules of O<sub>2</sub>

5 molecules of H<sub>2</sub> + 2 molecules of O<sub>2</sub> → 4 molecules of H<sub>2</sub>O + 1 molecule of H<sub>2</sub>

amount of the product formed is determined by the amount of the limiting reagent present

you must always use the amount of the limiting reagent to determine the amount of product that will be formed

steps in solving  
stoichiometry  
problems involving  
limiting reagents

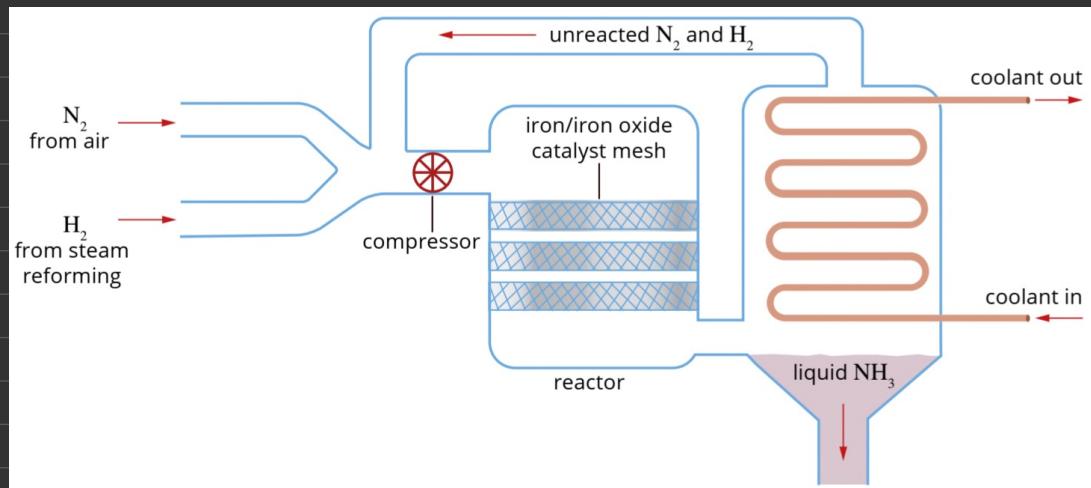
1. calculate amounts of both reactants
  2. choose one reactant (reactant A) and assume that all of it reacts
    - use the mol ratio to calculate how much of reactant B would be needed to react with it
  3. compare the amount of reactant B with the amount of reactant B available
    - is there enough of reactant B to fully react with reactant A
  4. if yes, A = limiting reagent
    - if no, B = limiting reagent
  5. amount of the limiting reagent can then be used to calculate the amounts of products formed in the reaction
- mole ratio = coefficient of unknown/coefficient of known

## 11.3 - some key products

ammonia	$\text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$ ammonia reacts with water polar $\text{NH}_3$ molecules form H-bonds with $\text{H}_2\text{O}$ molecules
Haber process	exothermic reaction $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ $\Delta H = -92 \text{ kJ/mol}$  reaction rate can be increased by: <ul style="list-style-type: none"> <li>- higher temp</li> <li>- catalyst is present</li> <li>- partial pressures of gaseous reactants are higher (higher pressure)</li> </ul>

Condition	Effect on equilibrium yield	Effect on reaction rate
Catalyst present	No effect	Increased
Increased temperature	Decreased	Increased
Increased pressure	Increased	Increased

- economic benefits from increased rate and yield outweigh the cost of maintaining high pressures



sulfuric acid	- dehydrating agent diprotic acid, when added to water it can donate 2 protons in 2-step ionisation process $\text{H}_2\text{SO}_4(\text{l}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{HSO}_4^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$ $\Delta H = -72 \text{ kJ/mol}$ $\text{HSO}_4^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{SO}_4^{2-}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$ $\Delta H = -22 \text{ kJ/mol}$
---------------	---

the contact process	<p>sulphuric acid is manufactured in stages from sulfur dioxide        - involves oxidation of sulfur dioxide to sulfur trioxide, followed by conversion to the acid  <math>\text{SO}_2</math> (from various sources) <math>\rightarrow \text{SO}_3 \rightarrow \text{H}_2\text{SO}_4</math></p>												
	<p><u>stage 1: sourcing or producing sulfur dioxide</u>        sulfur dioxide used to produce sulfur acid is from:        - combustion of sulfur recovered from natural gas + crude oil        - smelting of sulphide ores of copper, zinc or lead        - spraying molten sulfur under pressure into a furnace</p> $\text{S(l)} + \text{O}_2(\text{g}) \rightarrow \text{SO}_2(\text{g})$ $\Delta H = -297 \text{ kJ/mol}$												
	<p>- sulfur dioxide is then cooled for the next stage in the process</p> <p><u>stage 2: converting sulfur dioxide into sulfur trioxide</u></p> $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$ $\Delta H = -197 \text{ kJ/mol}$												
	<p>reaction between sulfur dioxide and oxygen = exothermic        higher reaction rate can be obtained by:</p> <table border="1" data-bbox="441 1291 1437 1448"> <thead> <tr> <th></th> <th>Higher temperature</th> <th>Higher pressure</th> <th>Presence of catalyst</th> </tr> </thead> <tbody> <tr> <td>Equilibrium yield</td> <td>Lower yield</td> <td>Higher yield</td> <td>No effect</td> </tr> <tr> <td>Reaction rate</td> <td>Higher reaction rate</td> <td>Higher reaction rate</td> <td>Higher reaction rate</td> </tr> </tbody> </table> <p>- generally a high pressure is used in the Haber process        - not the case for the contact process        - cost of maintaining a high pressure outweighs any added benefits of a higher reaction rate and higher yield in the contact process (atmospheric pressure is used instead)</p> <p><u>stage 3: absorption of sulfur trioxide and conversion to sulphuric acid</u>        sulfur trioxide reacts with water to form sulfuric acid  <math>\text{SO}_3(\text{g}) + \text{H}_2\text{O(l)} \rightarrow \text{H}_2\text{SO}_4(\text{aq})</math>  <math>\Delta H = -130 \text{ kJ/mol}</math></p>		Higher temperature	Higher pressure	Presence of catalyst	Equilibrium yield	Lower yield	Higher yield	No effect	Reaction rate	Higher reaction rate	Higher reaction rate	Higher reaction rate
	Higher temperature	Higher pressure	Presence of catalyst										
Equilibrium yield	Lower yield	Higher yield	No effect										
Reaction rate	Higher reaction rate	Higher reaction rate	Higher reaction rate										

this direct reaction with water is not used because too much heat is generated that a fine mist of acid is produced

1. sulfur trioxide gas dissolves almost totally in the acid to form a liquid known as oleum ( $H_2S_2O_7$ )  
 $SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$   
2. oleum obtained from the absorption tower is then mixed with water to produce sulphuric acid  
 $H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$

2 molecules of sulphuric acid produced for every one molecule of sulfuric acid that is introduced to the absorption tower

waste management      sulfur dioxide reacts with water in the rain and clouds  $\rightarrow$  sulphurous acid ( $H_2SO_3$ )

weak acid, donates a proton to water to form hydrogen sulfite ions  
 $SO_2(g) + H_2O(l) \rightleftharpoons H_2SO_3(aq)$   
 $H_2SO_3(aq) + H_2O(l) \rightleftharpoons HSO_3^-(aq) + H_3O^+(aq)$

## 12.1 - green chemistry

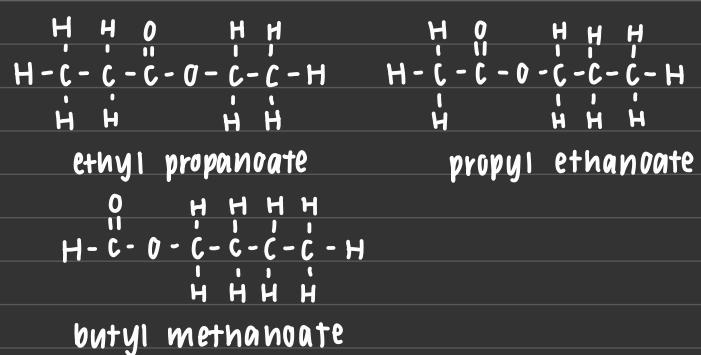
	<p>12 principles to guide chemists to producing environmentally sound products and processes</p> <ol style="list-style-type: none"><li>1. prevent waste</li><li>2. maximise atom economy</li><li>3. design less hazardous chemical syntheses</li><li>4. design safer chemicals and products</li><li>5. use safer solvents and reaction conditions</li><li>6. increase energy efficiency</li><li>7. use renewable raw materials</li><li>8. avoid chemical derivatives</li><li>9. use catalysts, not excess reactants</li><li>10. design chemicals and products that are biodegradable</li><li>11. analyse in real time to prevent pollution</li><li>12. minimise the potential for accidents</li></ol>
atom economy	atom economy = molar mass of desired product/molar mass of all reactants x100
green chemistry	hydrophobic substances are not attracted to, or will not mix homogeneously, with water
extracting gold in WA	$4\text{Au(s)} + 8\text{CN}^-(\text{aq}) + 2\text{H}_2\text{O(l)} + \text{O}_2(\text{g}) \rightarrow 4[\text{Au(CN)}_2]^- (\text{aq}) + 4\text{OH}^-(\text{aq})$



## 13.2 - functional groups

alcohols	<p>hydroxyl group (<math>-OH</math>) → saturated carbon          ↳ replaces a H in the structure of an alkane</p> <p>methanol : butan-2-ol :</p> $\begin{array}{c}   \\ -C-O-H \end{array}$ $\begin{array}{cccc}   &   &   &   \\ -C-C-C-C- \\   &   &   &   \\ O & & & H \\   & & &   \end{array}$	$\begin{array}{c}   \\ -C-O-H \end{array}$
naming alcohols	<ol style="list-style-type: none"> <li>① name of parent alkane, remove 'e', + 'ol'</li> <li>② number w/ lowest @ <math>-OH</math> functional group</li> <li>③ no. where hydroxyl group is bonded, add in the <math>-x-</math>          ↳ e.g. butan-2-ol</li> </ol>	
types of alcohols	<p>primary          ↳ bonded to 1 alkyl group</p> <p>secondary          ↳ bonded to 2 alkyl group</p> <p>tertiary          ↳ bonded to 3 alkyl group</p>	
primary amines	<p>amines - contain amino functional group          ↳ 1 nitrogen atom cov. bonded to 2 H atoms</p> $\begin{array}{c}   \\ -C-N-H \\   \\ H \end{array}$ $\begin{array}{c} H & H \\   &   \\ H-N-CH_3 \end{array}$ <p>methanamine</p> $\begin{array}{ccccc} H & & H & & H \\   & &   & &   \\ H-N-C-C-H \\   & &   & &   \\ H & & H & & H \end{array}$ <p>ethanamine</p> $\begin{array}{ccccccc} H & NH_2 & H & H \\   &   &   &   \\ H-C-C-C-C-H \\   &   &   &   \\ H & H & H & H \end{array}$ <p>butan-2-amine</p>	
naming amines	<ol style="list-style-type: none"> <li>① replace '-e' with '-amine'</li> <li>② if structural isomers are possible, insert a no. before '-amine'</li> </ol> $\begin{array}{c} H & H \\   &   \\ H-C-C-N-H \\   &   &   \\ H & H & H \end{array}$ $\begin{array}{c} H & H & H & H \\   &   &   &   \\ H-C-C-C-C-H \\   &   &   &   \\ H & N-H & H & H \\   & & &   \\ H & & & H \end{array}$	
carboxylic acids	<p>contain carboxyl functional group          ↳ <math>-COOH</math>          ↳ always located on 1 side of a hydrogen chain</p>	$\begin{array}{c} O \\    \\ H-C-O-H \end{array}$

naming carboxylic acids	<ul style="list-style-type: none"> <li>① suffix '-oic acid'</li> <li>② count carbons in functional group (e.g. <math>\text{C}_2\text{H}_3\text{COOH}</math> - 3 C's ∴ propanoic acid)</li> <li>③ carboxyl carbon = no 1</li> </ul>
	$\begin{array}{c} \text{H}-\text{C}=\overset{\text{O}}{\underset{\text{O}-\text{H}}{\diagdown}} \\ \text{methanoic acid} \end{array}$ $\begin{array}{c} \text{H} & & \text{H} \\   & &   \\ \text{H}-\text{C} & -\text{C}=\overset{\text{O}}{\underset{\text{O}-\text{H}}{\diagdown}} \\   & &   \\ \text{H} & & \text{H} \end{array}$ $\begin{array}{c} \text{H} & \text{H} & & \text{H} \\   &   & &   \\ \text{H}-\text{C} & -\text{C} & -\text{C}=\overset{\text{O}}{\underset{\text{O}-\text{H}}{\diagdown}} \\   &   &   \\ \text{H} & \text{H} & \text{H} \end{array}$ <p style="text-align: center;"><math>\text{HCOOH}</math>                            <math>\text{CH}_3\text{COOH}</math>                            <math>\text{CH}_3\text{CH}_2\text{COOH}</math></p>
structural isomers of carboxylic acids	- the C can double bond to one O and single bond to another
	$\begin{array}{c} \text{CH}_3-\text{CH}_2-\text{CH}-\overset{\text{O}}{\underset{\text{CH}_3-\text{OH}}{\diagdown}} \end{array}$
primary amides	<p>contain carbonyl functional group attached to an amino functional group except 1 -OH is replaced w/ -NH<sub>2</sub></p> <p>↳ N is bonded to 2 H atoms (in primary)</p> <p>amide = <math>-\text{CONH}_2</math></p> $\begin{array}{c} \text{H}-\overset{\text{O}}{\underset{\text{H}}{\diagdown}}-\text{N}-\text{H} \end{array}$ <p style="text-align: right;">always @ end</p>
naming amides	<ul style="list-style-type: none"> <li>① carbon 1 = amide group</li> <li>② suffix 'amide'</li> </ul>
esters	<p>reaction of carboxylic + alcohol (heated in the presence of sulfuric acid)</p> <p>- contains carbonyl group attached to an oxygen linked to another C</p> $\begin{array}{c} \text{-C}=\overset{\text{O}}{\underset{\text{O}-\text{H}}{\diagdown}}- \end{array}$ $\begin{array}{c} \text{-COOH-} \quad \text{or} \quad \text{-CO}_2- \end{array}$
esterification	
	<p>- carboxylic func. group of carboxylic acid + hydroxyl functional group of the alcohol</p> <p>↳ small molecule (water) is formed = condensation reaction</p>
	$\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}=\overset{\text{O}}{\underset{\text{O}-\text{H}}{\diagdown}} \end{array} + \begin{array}{c} \text{H} & \text{H} & \text{H} \\   &   &   \\ \text{H}-\text{O}-\text{C} & -\text{C} & -\text{C}-\text{H} \end{array} \xrightarrow{\text{H}_2\text{SO}_4} \begin{array}{c} \text{H} & \text{O} \\   &    \\ \text{H}-\text{C} & -\text{C}-\text{O} & -\text{C}-\text{C}-\text{H} \\   &   &   \\ \text{H} & \text{H} & \text{H} \end{array} + \begin{array}{c} \text{H} \\   \\ \text{O}-\text{H} \end{array}$
naming esters	<ul style="list-style-type: none"> <li>① locate the functional group + the carbonyl carbon</li> <li>② starting from this carbon, determine the no. of C atoms in the chain attached to the stem name, adding '-oate'</li> <li>③ add the alkyl group bonded to the singly bonded O atom in front of the name</li> </ul>

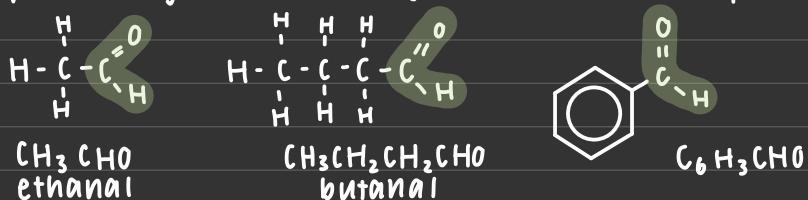


## aldehydes

carbonyl @ end

-CHO

simplest aldehyde, methanal ( $\text{HCHO}$ ) → known as formaldehyde



## naming aldehydes

- ① locate the functional group + the carbonyl carbon
  - ② add suffix '-al'

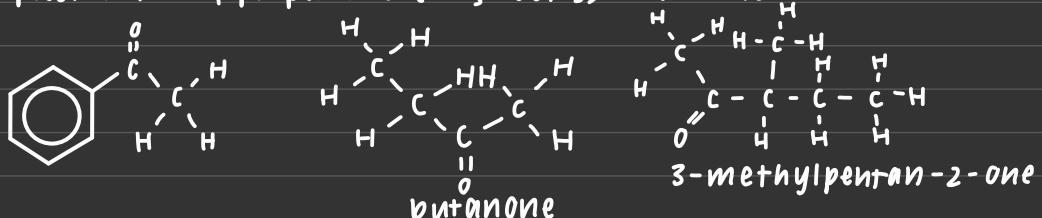
## **ketones**

carbonyl carbon is attached to other carbon atoms

↳ never @ the end

- 60 -

simplest ketone, propanone ( $\text{CH}_3\text{COCH}_3$ ) → acetone



## naming ketones

- ① identify end of hydrocarbon chain closest to the functional group
  - ② use prefix of no. of C atoms and suffix '-one', indicating the position of the double-bonded O by inserting the no. between the prefix + suffix in the final part of the name

## chapter 13.3 - properties of organic compounds

### B.P's of alkanes

methane	-162
ethane	-89
propane	-45
butane	-0.5
pentane	36
hexane	69

alkanes = non-polar

↳ only IMF = weak dispersion forces  
 as C chain ↑, overall attraction F ↑ → more S.A. ∴ more contact ∴ more bonds ∴ stronger  
 ↳ because ↑ strength of temporary  
 ↳ ∵ as ↑ strength of IMF. ↑ BP  
 straight-chain fit closer together ∴ ↑ BP

### B.P's of alkenes

non-polar

same as alkanes

### solubility in water

non-polar ∴ insoluble in water

water = held by H-bonds ∴ weak dispersion cannot overcome

e.g. hexane floats above water + is immiscible

### solubility in organic solvent

alkanes mix w/ other non-polar liquids, such as alkanes + symmetrical haloalkanes

### B.P's

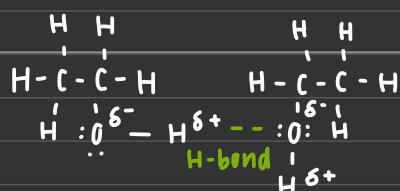
alkane	butane	C <sub>4</sub> H <sub>10</sub>	-1°C
alcohol	propan-1-ol	C <sub>3</sub> H <sub>7</sub> OH	97.2°C
carboxylic acid	ethanoic acid	CH <sub>3</sub> COOH	118°C
amine	propan-1-amine	C <sub>3</sub> H <sub>7</sub> NH <sub>2</sub>	49°C
amide	ethanamide	CH <sub>3</sub> CONH <sub>2</sub>	210°C

### B.P's of alcohols

↑BP of alcohols are because of H-bonds between neighbouring alcohol molecules

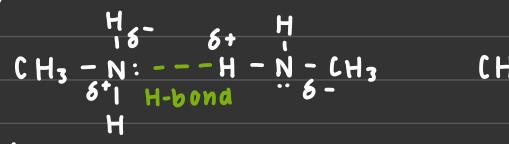
only kind of IMF between non-polar alkane molecules are much weaker dispersion forces

O is more electronegative than H so the O-H bond in the hydroxyl group is a polar bond



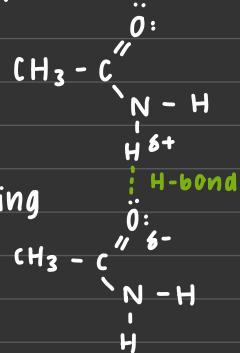
## B.P's of amines + amides

highly polar N-H bonds  $\therefore$  can form H bonds



### amines

H-bonds form between non-bonding pair of e<sup>-</sup> on the electroneg. N atom + partially pos. H atom on another amine molecule

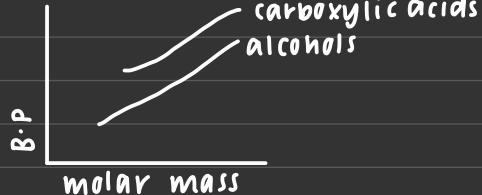
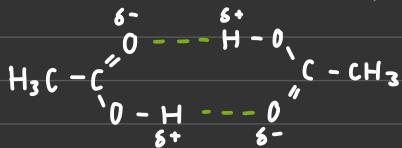


### amides

H-bonds form between non-bonding e<sup>-</sup> pairs on the O atoms of 1 molecule + the partially pos. H atom on a neighbouring molecule

## B.P's of carboxylic acids

dimers = 2 H-bonds are formed between molecules



## Effect of chain length on B.P

B.P  $\uparrow$  as molar mass  $\uparrow$

in alcohols, IMF between -OH groups  $= \uparrow$  B.P

$\uparrow$  in molar mass  $= \uparrow$  dispersion F  $\therefore \uparrow$  strength

hydroxyl group becomes increasingly 'crowded' from the 1° alcohol  $\rightarrow$  3° alcohol isomers

alkyl groups restricts the ability to form H-bonds w/ other molecules  
 $\therefore$  B.P's  $\downarrow$  from 1°  $\rightarrow$  3°

## Solubility in water

Small alcohols + amines dissolve in water because H-bonds can form between the polar functional groups of the molecules + the adjacent water molecules

alcohols = H-bonds between partially pos. H of hydroxyl group + lone e<sup>-</sup> pair of adjacent H<sub>2</sub>O molecule

& also partially pos. H in H<sub>2</sub>O + lone e<sup>-</sup> pair on the alcohol

<b>solubility + chain length</b>	<p>solubility in water of alcohols, amines, amides + carboxylic acids <math>\downarrow</math> w/ <math>\uparrow</math> chain length      longer hydrocarbon chains disrupt the H-bonds between <math>\text{H}_2\text{O}</math> molecules      ↳ hydroxyl group can form H-bonds w/ <math>\text{H}_2\text{O}</math> but the hydrocarbon 'tail' can't      chain length <math>\uparrow</math>, non-polar nature <math>\uparrow</math> <math>\therefore</math> alcohol is less soluble</p>														
<b>solubility in organic solvents</b>	<p>alcohols = more soluble in organic solvents as they get larger</p>														
<b>properties + uses of alcohols</b>	<ul style="list-style-type: none"> <li>- fuels</li> <li>combustion</li> </ul> $\text{C}_2\text{H}_5\text{OH}(l) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(g)$ <p><math>\uparrow</math> size <math>\uparrow</math> B.P.</p> <p>all alcohols are liquid @ room temp.      alkanes + alkenes are gases</p> <table border="1"> <caption>Data points estimated from the graph</caption> <thead> <tr> <th>No. of carbon atoms</th> <th>B.P.</th> </tr> </thead> <tbody> <tr><td>1</td><td>10</td></tr> <tr><td>2</td><td>15</td></tr> <tr><td>3</td><td>20</td></tr> <tr><td>4</td><td>25</td></tr> <tr><td>5</td><td>30</td></tr> <tr><td>6</td><td>35</td></tr> </tbody> </table>	No. of carbon atoms	B.P.	1	10	2	15	3	20	4	25	5	30	6	35
No. of carbon atoms	B.P.														
1	10														
2	15														
3	20														
4	25														
5	30														
6	35														
	<p><math>\uparrow</math> B.P. is because of -OH group      ↳ allows H bonding to occur</p> $\begin{array}{c} \text{H} & & \cdots \text{O}^{\delta-} \text{H} \\ & \backslash & / \\ \text{H} - \text{C} - \text{O} & & \text{H} \\ & / & \backslash \\ \text{H} & & \text{H} - \text{O}^{\delta-} \text{H} \end{array}$														
<b>properties + uses of carboxylic acids</b>	<p>electrons are drawn away from the H atom, enabling it to form a <math>\text{H}^+</math>(aq) ion so the functional group can act as an acid</p> <ul style="list-style-type: none"> <li>- weak acids</li> </ul>														
<b>physical properties of aldehydes, ketones + esters</b>	<p>all held by dipole-dipole</p>														
<b>boiling points</b>	<p>aldehydes, ketones + esters <math>\rightarrow</math> contain C=O double bond      ↳ polar (O = more electroneg.)</p> <p>Strength of dipole-dipole = <math>\uparrow</math> B.P than similar sized alkanes      ↳ but not as <math>\uparrow</math> as similar sized alcohols (they have H bonds)</p>														
<b>solubility</b>	$\text{R}-\overset{\delta+}{\underset{\delta-}{\text{C}}}-\ddot{\text{O}}-\text{H} \cdots \text{H}-\ddot{\text{O}}-\text{R}'$ <p>strength of this is enough to make small aldehydes, ketones + esters soluble in water</p>														

<b>solubility in organic solvents</b>	↑ in length = more soluble in non-polar solvents - opposite to the trend observed in H <sub>2</sub> O
<b>properties + uses of esters</b>	- polar - no free hydroxyl groups ∴ no H-bonds - ∵ ↓ B.P than carboxylic acids + alcohols of similar molecular mass small esters are liquids @ room temp.

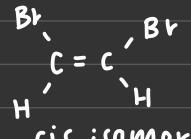
## chapter 13.4 - isomers review

### isomers

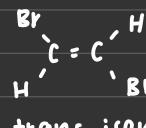
- structural
- geometric (cis-trans) ] 2 types

### geometric isomers

double bonds cannot rotate



cis isomer

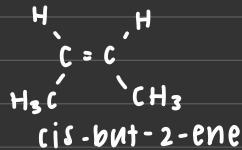


trans isomer

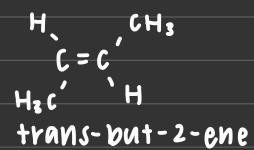
1,2-dibromoethene

in longer alkanes, the longest alkyl groups attached to the C atoms in the double bond are used to determine cis vs trans

- cis : longest alkyl groups on each C are on same side of the double bond
- trans: " " are on opposite sides of the double bond



cis-but-2-ene



trans-but-2-ene

## chapter 13.5 - IUPAC nomenclature



- ① longest carbon chain, must include func. group
- ② names + locations of branches
- ③ no's for attached groups
- ④ no's + letters separated by --
- ⑤ no's separated by , 's
- ⑥ alphabetical func. groups
- ⑦ di-, tri-, tetra-



organic molecules

carbon chain is numbered from end closest to the func. group



## determining molecular formulae

- ① empirical formula
- ② molar mass of empirical formula
- ③ no. of empirical formula units in the compound
- ④ write the molecular formula

molar mass in g·mol<sup>-1</sup> of 1 unit of the empirical

$$M(\text{CH}_3) = 12.01 + (3 \times 1.008) = 15.03$$

no. of empirical formula

$$\text{no.} = \frac{\text{molar mass}}{\text{molar mass of empirical unit}} = \frac{30}{15.03} = 2$$

multiply the empirical by this factor to determine the molecular formula

$$2 \times \text{CH}_3$$

$$= \text{C}_2\text{H}_6$$

## chapter 14.1 - chemical properties of alkanes

### reactions of alkenes

#### combustion in air



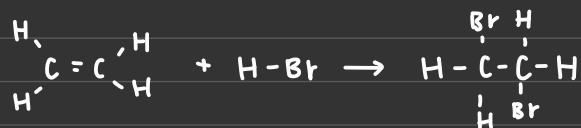
in a limited supply of O = incomplete combustion can occur + CO is produced



#### addition

during addition reactions:

- 2 reactant molecules combine to  $\rightarrow$  1 product molecule
- C=C  $\rightarrow$  single bond
- unsaturated  $\rightarrow$  saturated



#### substitution

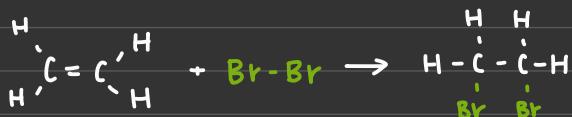
alkanes + halogens  $\rightarrow$  haloalkanes



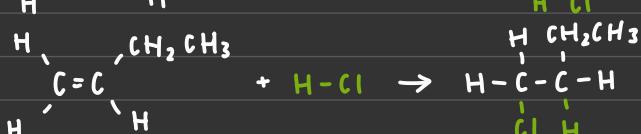
for each molecule of Cl<sub>2</sub> that reacts, a H atom on the alkane is replaced by a Cl atom

### reactions of alkenes w/ H

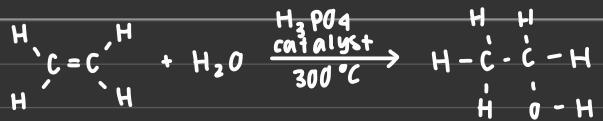
react w/ H in the presence of a metal catalyst  $\rightarrow$  alkanes  
hydrogenation



### alkenes w/ H halides



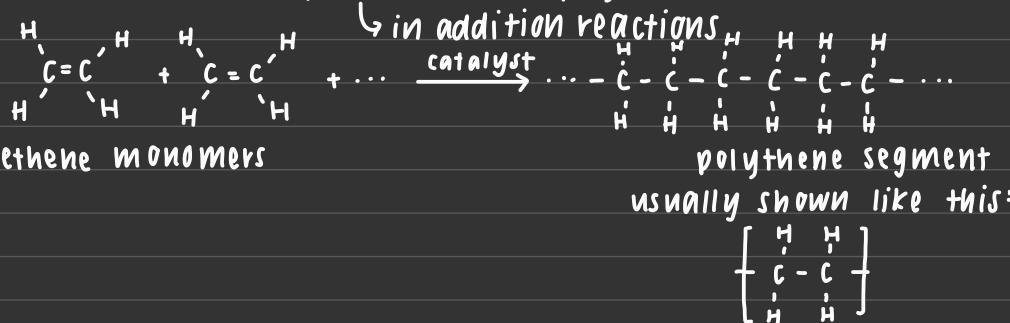
## alkenes + H<sub>2</sub>O



## hydration reaction

# addition polymerisation

alkenes can react w/ each other → polymers



## chapter 14.2 - chemical properties of alcohols

## combustion of alcohols

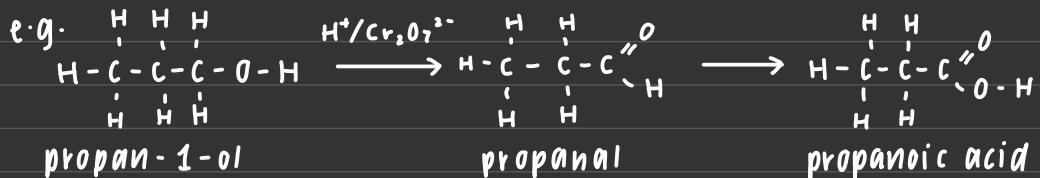
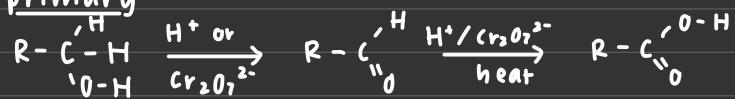


## oxidation

primary alcohols → aldehydes  
secondary alcohols → ketones  
tertiary alcohols = not oxidised

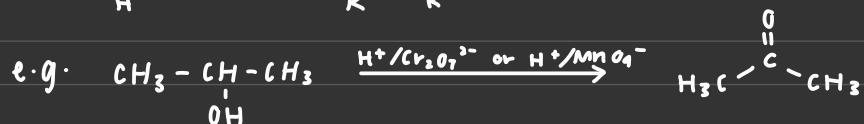
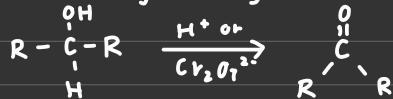
→ carboxylic  
strong oxidising agents:  
 $\text{KMnO}_4$        $\text{K}_2\text{Cr}_2\text{O}_7$

primary



## secondary

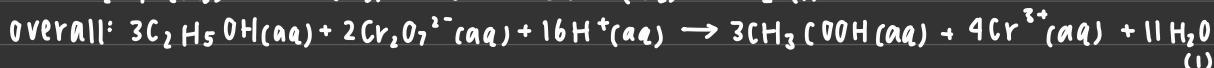
- oxidised by strong oxidising agents



during the oxidation of alcohols, ↑ in no. of C-O bonds and a simultaneous ↓ in no. of C-H bonds

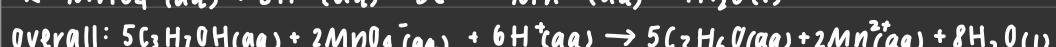
↳ in tertiary, the carbon attached to the hydroxyl group doesn't have a C-H bond to break ∴ oxidation cannot occur @ the C atom

# writing equations



e.g. 2

propan-1-ol w/ acidified KMnO<sub>4</sub>



## chemical properties of carboxylic acids

### ionisation in $H_2O$

carboxylic = w.a



## reactions w/ metals

carboxylic acids + metal oxides/hydroxides  $\rightarrow$  metal salts +  $H_2O$



carboxylic acids + metal carbonates/hydrocarbonates  $\rightarrow$  salt,  $H_2O$ ,  $CO_2$



ionic:



carboxylic acids + reactive metals (like Na/Mg)  $\rightarrow$  salt +  $H_2$



ionic:



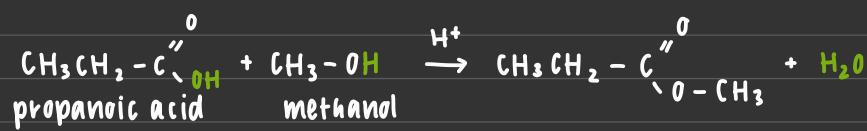
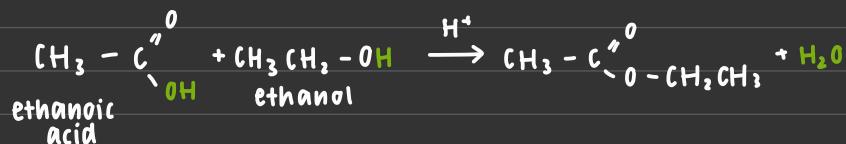
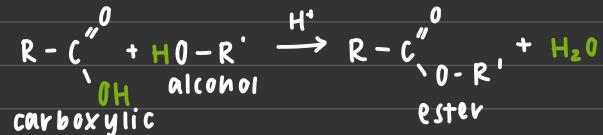
## carboxylic + alcohols

reactions w/ 2 reactants + the elimination of a small molecule (e.g.  $H_2O$ )

= condensation reactions

esters are made by  $\uparrow$  between alcohol + carboxylic

↳ a.k.a esterification

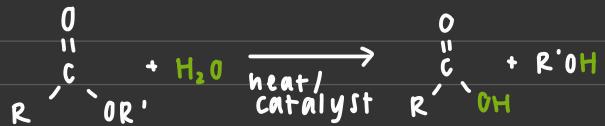


### esterification

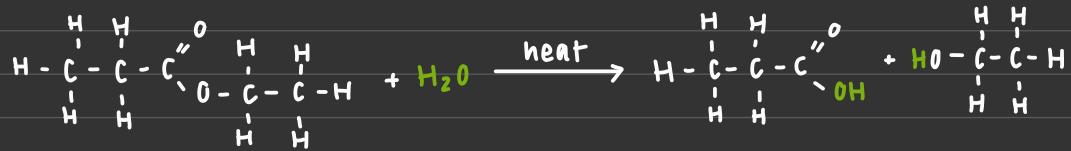
$H$  from hydroxyl group of alcohol +  $OH$  group from carboxylic acid  $\rightarrow H_2O$   
 ↳ this is eliminated

## hydrolysis of esters

condensation between carboxylic + alcohols = reversible  
esters + H<sub>2</sub>O → carboxylic + alcohol  
↳ hydrolytic / hydrolysis  
- catalysed by alkali / dilute acid



e.g. ethyl propanoate → ethanol + propanoic acid

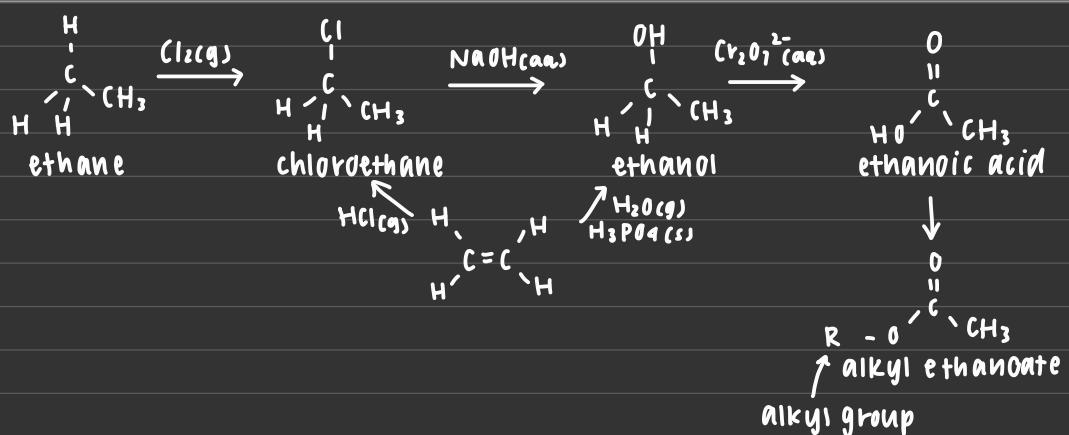


when catalysed by an alkali (e.g. OH), products = alcohol + sodium salt of the carboxylic  
sodium salt → carboxylic acid by + dilute acid (e.g. HCl)

hydrolysis of esters by metal hydroxides → a salt of carboxylic  
↳ + excess acid regenerates the carboxylic

## chapter 14.4 - organic synthesis intro

### simple reaction pathways



### reaction sequences



ethyl ethanoate is formed from ethanoic acid + ethanol

#### steps

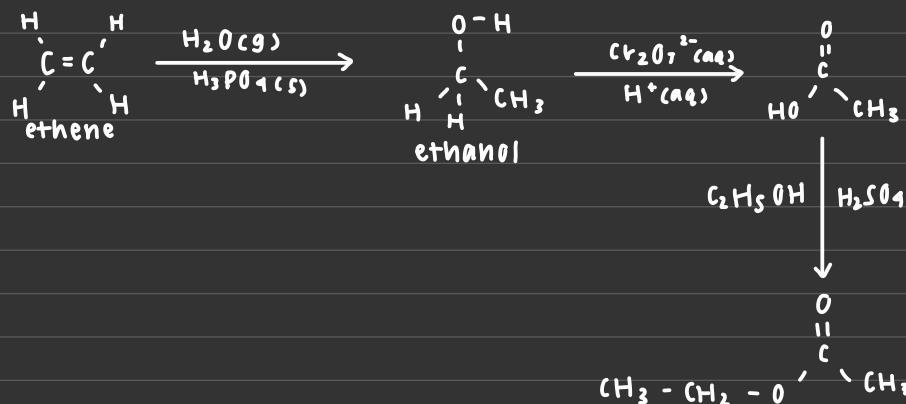
① ethanol is synthesised directly by hydration of ethene in presence of phosphoric acid (catalyst)



② ethanoic acid is synthesised by oxidising some of the ethanol produced in ①



③ ethyl ethanoate is produced by the condensation reaction between ethanoic acid + ethanol in presence of sulfuric acid (catalyst)



length ↑ = more rigid  
(↑ dispersion F between)

SHAPE:  
branched or linear



further apart  
= less dense  
∴ ↓ IMF attraction  
= ↑ flexibility

plastic means  
easily malleable

elastomers = when only  
occasional cross links  
(moving back to  
original positions e.g.  
rubber bands)

cross linking = cov.  
bonded to neighbouring  
= polymer network



usually thermosetting  
polymers decompose/  
burn when heated

+ hard / rigid

↳ do not soften as  
bonds are too  
strong

## ADDITION POLYMERISATION

alkenes + themselves → long chains  
(addition polymers)

monomer ethene + itself → polyethene

/ \  
unsaturated no double  
(because of C=C) bonds  
= saturated

double bond breaks  
when polymerised

+ new cov. bonds between  
C atoms on nearby monomers

## free radical polymerisation

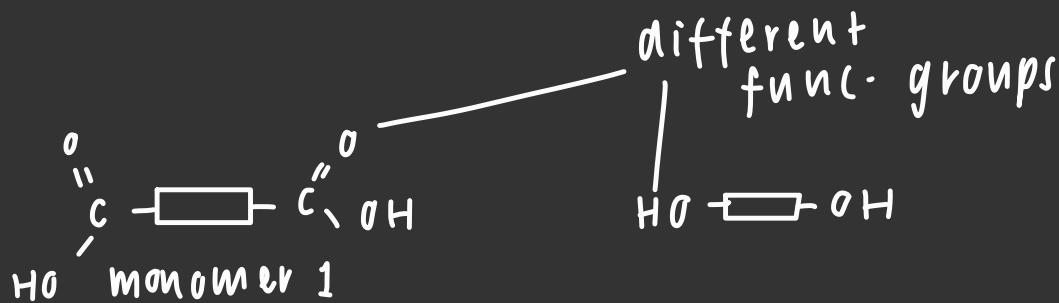
↑ highly reactive atoms  
(unpaired e<sup>-</sup>'s) ← attack sides of  
↑ polymer chain = branching ↗ cannot pack  
break (=)'s in ethane closely together  
monomers to start  
polymerisation reaction ∵ weaker as  
particles are further apart

## CONDENSATION POLYMERISATION

monomer needs 2 func. groups

one on each end

small molecules are produced



### differences

#### addition

monomers = unsaturated

(=) or ( $\equiv$ )

no byproducts produced

backbone = long C-C chain

#### condensation

monomer = 2 func. groups  
(react w/ neighbours)

small molecules = byproducts  
e.g.  $\text{H}_2\text{O}$ ,  $\text{HCl}$  etc.

back bone = func. groups  
e.g. amines or esters



# REDOX TITRATION

$$\frac{18 \cdot 6 + 17 \cdot 6 + 17 \cdot 2 + 17 \cdot 7}{4} = \text{average titre}$$

$V = 17 \cdot 775 \text{ mL}$   
 $M (\text{random no.}) = 0 \cdot 1 M$   
 $m (\text{steel wool}) = 108 \text{ g}$

neutralise  
 $\text{mol of acid} = \text{mol of } \text{OH}^-$   
 $\text{H}^+ = \text{OH}^- \leftarrow \text{mols of both}$

$$\text{mols} = (M)(L)$$

①  $\text{mol H}^+ = \text{mol OH}^-$

② check if diprotic

③ mol known

④ mass known

⑤ % mass

example Q:



5.54g is neutralised by

0.1M NaOH

∴ mass of acetic acid in vinegar = ?

② check if diprotic  $\downarrow$  neutralise  
 $\therefore \text{mol of H}^+ = \text{mol of OH}^-$   
 $1 \text{ mol CH}_3\text{COOH} = 1 \text{ mol NaOH}$   
 $\text{mol} = (M)(L)$

③ mol acetic acid =  $(0 \cdot 03010)(0 \cdot 1)$   
 $\uparrow L \quad \uparrow M$   
 $= 0 \cdot 00301 \text{ mol}$

④  $m(\text{acetic}) = 0 \cdot 00301 \text{ mol} \times 60 \cdot 052 \text{ g/mol}$   
 $= 0 \cdot 181 \text{ g}$

⑤ % mass =  $\frac{0 \cdot 181}{5 \cdot 54} \times 100$   
 $= 3 \cdot 26 \%$



## 16.1 - fats and oils

saturated and unsaturated fatty acids	<p>saturated fatty acids</p> <ul style="list-style-type: none"><li>- hydrocarbon chains w/ C-C bonds</li></ul> <p>monounsaturated fatty acids</p> <ul style="list-style-type: none"><li>- one C=C double bond double bond in the hydrocarbon chain</li></ul> <p>polyunsaturated fatty acids</p> <ul style="list-style-type: none"><li>- more than one C=C double bond in the hydrocarbon chain</li></ul>
uses of fats and oils	<ul style="list-style-type: none"><li>- soap</li><li>- biodiesel</li></ul>

## 16.2 - production of soaps

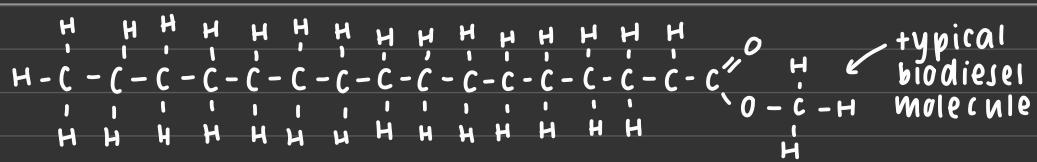
detoxifiers	- long hydrocarbon chain is sourced from petroleum products  anionic detergents - active constituent is negatively charged - composed of a sulfonate group attached to a long carbon chain (often by a benzene ring)
	$\underbrace{\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2}_{\substack{\text{alkyl group (a dodecyl group)} \\ \uparrow 12 \text{ carbons}}} - \text{C}_6\text{H}_5 - \text{SO}_3^- \text{Na}^+$ <p style="text-align: center;">benzene      ↑ sulfonate</p>

## 16.3 - the cleaning action of soaps and detergents

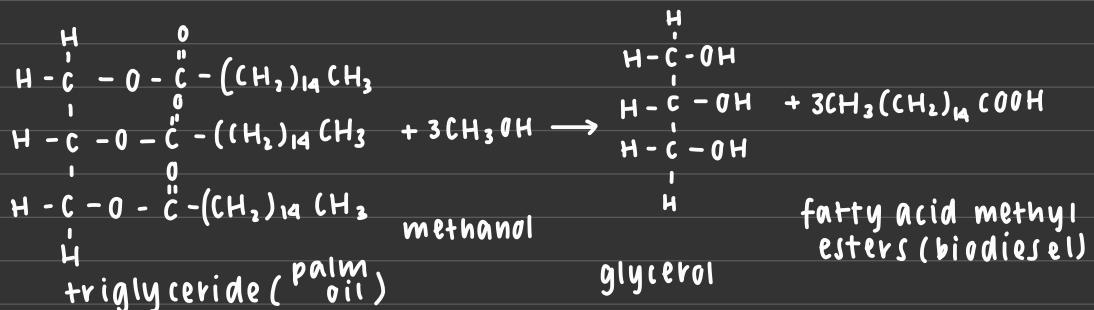
soap in water	<p>tend to form clumps</p> <ul style="list-style-type: none"><li>- hydrophilic ends are on the outside (in contact with the water)<ul style="list-style-type: none"><li>- hydrophilic: can form <b>strong forces of attraction with water</b></li><li>- in this case: ion-dipole forces</li></ul></li><li>- hydrophobic ends are the centre (in contact with each other)</li></ul> <p>clump: stable arrangement - micelle</p>
cleaning action	<p>non-polar ends are able to position in oils/grease</p> <p>hydrophilic ends are exposed to the water</p> <p>water is attracted to the polar ends of the soap</p> <p>oil particle is lifted from the source</p> <p>non-polar sections embed themselves around the oil</p> <p>charged end of the soap protrudes into the water</p> <p>oil surrounded by soap molecules is stable</p> <p>cannot reattach to the source</p> <p>polar solvents can remove n.p. stains</p> <p>soaps/detergents = surfactant</p>

## 16.4 - production of biodiesel

### transesterification

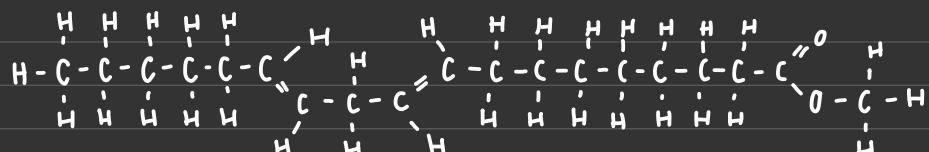


- triglyceride  $\rightarrow$  biodiesel by warming it with alcohol (usually methanol)
- called transesterification
- requires a catalyst
- carried out using a base (KOH or lipase usually)
  - lipase = an enzyme (protein produced by a living organism)

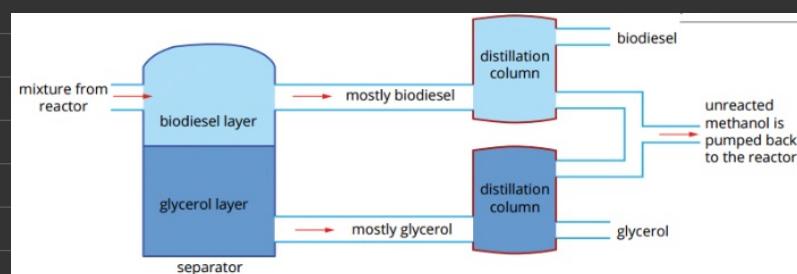


- often referred to fatty acid esters
- made of fatty acid + simple alcohol
- fatty acid: carboxylic acid with long hydrocarbon chains

triglycerides from plants often produce unsaturated esters



### manufacturing biodiesel



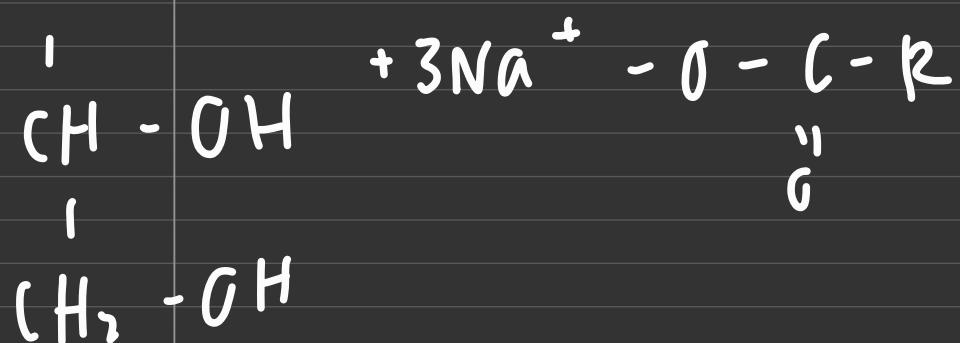
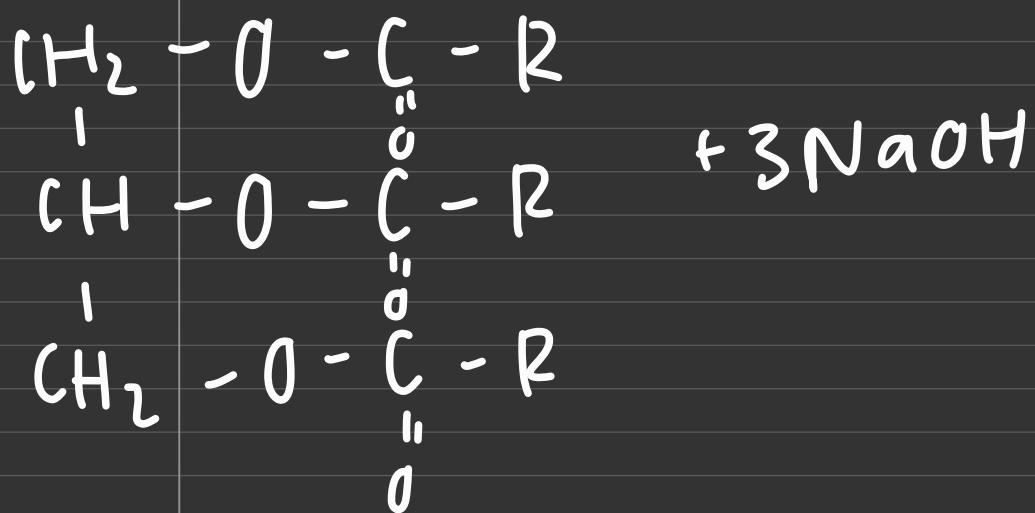
### choosing a catalyst

Method	Temperature (°C)	Pressure (kPa)	Time (min) in reactor	Catalyst use	Yield (%)
Base-catalysed	60–70	140–400	30–60	Only able to be used for one cycle of the production process	96–98
Lipase-catalysed	20–37	101.3	at least 150	Can be used many times	Typically 80 (can be as high as 92)

green chemistry	<p>12 principles to guide chemists to producing environmentally sound products and processes</p> <ol style="list-style-type: none"><li>1. prevent waste</li><li>2. maximise atom economy</li><li>3. design less hazardous chemical syntheses</li><li>4. design safer chemicals and products</li><li>5. use safer solvents and reaction conditions</li><li>6. increase energy efficiency</li><li>7. use renewable raw materials</li><li>8. avoid chemical derivatives</li><li>9. use catalysts, not excess reactants</li><li>10. design chemicals and products that are biodegradable</li><li>11. analyse in real time to prevent pollution</li><li>12. minimise the potential for accidents</li></ol>
wider environmental considerations	the burning of biodiesel and petrodiesel produces CO <sub>2</sub>

scribble

Soap



## 17.1 - amino acids

amino acids as zwitterions	<p>amino acids contain polar amino and carboxyl func. groups</p> <ul style="list-style-type: none"> <li>- therefore amino acids can form H bonds with H<sub>2</sub>O molecules and are soluble in water</li> <li>- -NH<sub>2</sub> group can act as a base, accepts a proton = -NH<sub>3</sub><sup>+</sup> group</li> <li>- -COOH group can act as an acid, don'tate a proton = -COO<sup>-</sup> group</li> <li>- = amino acid molecule in (aq) solution can form +H<sub>3</sub>N-CH(R)-COO<sup>-</sup></li> </ul>
	<p>molecule is known as a zwitterion or a dipolar ion</p> <ul style="list-style-type: none"> <li>- contains positive and negative charges as well as no charge overall</li> <li>- amino acids have a high MP because of zwitterion being present in the solid state <ul style="list-style-type: none"> <li>- amino acids are held together by ionic bonds in the solid state</li> <li>- ionic bonds require a high amount of E to break, = high MP</li> </ul> </li> </ul>
acid-base properties of amino acids	<p><math>\begin{array}{c} \text{H} &amp; \text{R} \\   &amp;   \\ \text{H}-\text{N}^+-\text{C}-\text{C}^{\prime\prime}\text{O} \\   &amp;   \\ \text{H} &amp; \text{H} \end{array} \leftarrow \text{structure of a zwitterion}</math></p> <ul style="list-style-type: none"> <li>- dual acid-base nature of amino acids = depends on the solution's pH as to what form is predominant</li> <li>- at pH=5-7, zwitterion +H<sub>3</sub>N-CH(R)COO<sup>-</sup></li> <li>- low pH, zwitterion +H<sub>3</sub>N-CH(R)-COO<sup>-</sup>(aq) + H<sub>3</sub>O<sup>+</sup>(aq) <math>\rightleftharpoons</math> +H<sub>3</sub>N-CH(R)-COOH(aq) + H<sub>2</sub>O(l) <ul style="list-style-type: none"> <li>- if the concentration of H<sub>3</sub>O<sup>+</sup> is very high, position of equilibrium is to the right</li> <li>- high pH, anion H<sub>2</sub>N-CH(R)-COO<sup>-</sup> is the most abundant, OH<sup>-</sup> ions in solution can react with amino acid: +H<sub>3</sub>N-CH(R)-COO<sup>-</sup>(aq) + OH<sup>-</sup> <math>\rightleftharpoons</math> H<sub>2</sub>N-CH(R)-COO<sup>-</sup>(aq) + H<sub>2</sub>O(l) <ul style="list-style-type: none"> <li>- if concentration of OH<sup>-</sup>(aq) is very high, position of equilibrium is to the right</li> </ul> </li> </ul> </li> </ul> <p><math>\begin{array}{c} \text{H} &amp; \text{R} \\   &amp;   \\ \text{H}-\text{N}^+-\text{C}-\text{C}^{\prime\prime}\text{O} \\   &amp;   \\ \text{H} &amp; \text{H} \end{array}</math> cation (low pH)    <math>\begin{array}{c} \text{R} \\   \\ \text{H}-\text{N}^+-\text{C}-\text{C}^{\prime\prime}\text{O} \\   \\ \text{H} \end{array}</math> zwitterion (no overall charge (intermediate pH))    <math>\begin{array}{c} \text{H} &amp; \text{R} \\   &amp;   \\ \text{N}-\text{C}-\text{C}^{\prime\prime}\text{O}^- \\   &amp;   \\ \text{H} &amp; \text{H} \end{array}</math> anion (high pH)</p> <ul style="list-style-type: none"> <li>- side chain contains a func. group w/ acid-base properties</li> </ul>

## 17.2 - the formation of proteins

## 17.3 - primary and secondary structures of proteins

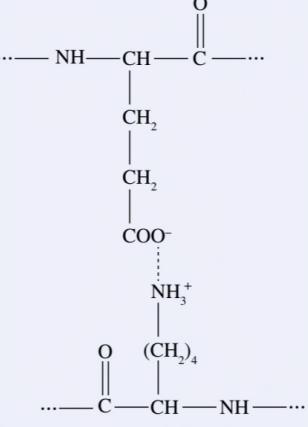
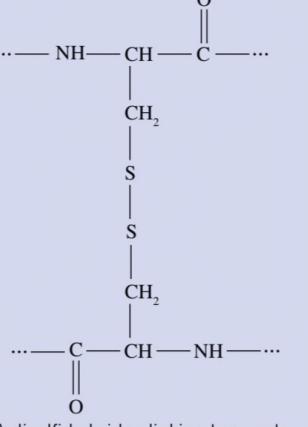
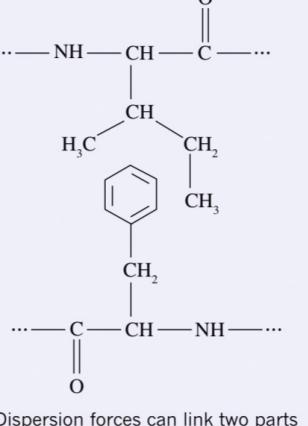
primary structure of proteins	<p>number, type and sequence of amino acids = primary structure</p> <ul style="list-style-type: none"> <li>- written from left to right (starting with N-terminal amino acid and ending with the C-terminal amino acid)</li> </ul> <p>the function of a protein is a consequence of its shape, which in turn is determined by the order in which amino acids are joined together, the primary structure</p>
secondary structure of proteins	<p>coiling and pleating of sections of a protein molecule produce a secondary level of structure in a protein</p> <ul style="list-style-type: none"> <li>- polar <math>-\text{NH}_2</math> group in one peptide link, polar <math>-\text{C=O}</math> group in another peptide link can form at regular intervals <ul style="list-style-type: none"> <li>- spiral sheet <math>\rightarrow</math> alpha-helix</li> <li>- sections line up parallel <math>\rightarrow</math> beta-pleated-sheet</li> </ul> </li> </ul> <p>highly ordered segments, stabilised by H-bonds = secondary structure</p>
alpha-helices	<ul style="list-style-type: none"> <li>- results from extensive H-bonding between peptide links in the polypeptide chain</li> <li>- H-bonds = attraction between H of a <math>-\text{NH}</math> group (partial positive) w/ O of a <math>-\text{C=O}</math> group of a peptide link (partial negative)</li> </ul> <p>the H bonds = coil into helix (spring shape)</p>
beta-pleated-sheets	<ul style="list-style-type: none"> <li>- can form between peptide links</li> <li>- produce regions where 2 or more parts of the polypeptide chains line up parallel to each other</li> <li>- backbone of the protein chain (<math>-\text{N-C-C-N-C-C-N-C-C-}</math>) allow H-bonds to form at regular intervals</li> <li>- stabilises the protein structure</li> </ul> <p>The diagram illustrates the backbone of a beta-pleated sheet. It shows a repeating sequence of peptide bonds (<math>-\text{C}(=\text{O})\text{NH}-</math>). The carbonyl carbon (<math>\text{C=O}</math>) is bonded to an oxygen atom (<math>\text{O}</math>) above it and a nitrogen atom (<math>\text{N}</math>) below it. The nitrogen atom is bonded to a hydrogen atom (<math>\text{H}</math>) above it and a carbon atom (<math>\text{C}</math>) to its right. This carbon atom is bonded to a hydrogen atom (<math>\text{H}</math>) above it and a side chain (<math>\text{CH}_3</math>) below it. The side chain (<math>\text{CH}_3</math>) is further bonded to an oxygen atom (<math>\text{OH}</math>) below it. The entire sequence is shown twice, with the second sequence offset to the right.</p>

## 17.4 - tertiary structure of proteins

overall shape of a protein	<p>tertiary structure = overall 3D shape adopted by the protein molecule</p> <ul style="list-style-type: none"> <li>- side chains can interact with each other in a number of ways causing folding into its 3D shape</li> </ul> <p>side chains can be:</p> <ul style="list-style-type: none"> <li>- relatively large</li> <li>- contain polar functional groups</li> <li>- become charged depending on the pH of their surroundings</li> </ul> <p>amino acids have hydrophobic (n.p.) chains</p> <ul style="list-style-type: none"> <li>- tend to fold towards the interior of protein molecules away from contact with H<sub>2</sub>O</li> </ul> <p>side chains of amino acids influence the properties of the amino acid. There are 4 main groups of amino acids, which can be classified as polar, non-polar, acidic or basic</p>
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## bonding in the tertiary structure of proteins

Bond type	Required components in side chain	Visual representation
Hydrogen bonds	Contains -O-H, -N-H or -C=O	<p>A hydrogen bond linking two parts of a polypeptide chain</p>
Dipole-dipole interactions	Any polar group such as those containing -S-H, -O-H or -N-H	<p>A dipole-dipole interaction linking two parts of a polypeptide chain</p>

Bond type	Required components in side chain	Visual representation
Ionic interactions	Contains $\text{--NH}_3^+$ and another group that contains $\text{--COO}^-$	 <p>An ionic interaction linking two parts of a polypeptide chain</p>
Covalent cross-links	Cysteine side groups react to form a disulfide bridge ( $\text{--S--S--}$ )	 <p>A disulfide bridge linking two parts of a polypeptide chain</p>
Dispersion forces	Any non-polar group	 <p>Dispersion forces can link two parts of a polypeptide chain</p>

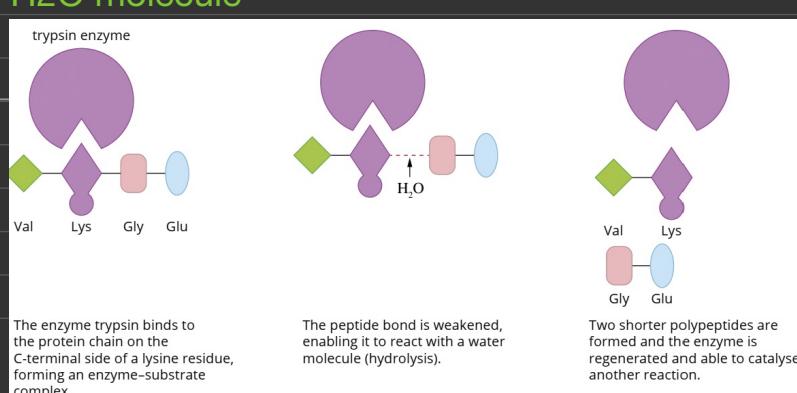
## 18.1 - investigating proteins

protein data bank	<ul style="list-style-type: none"><li>- database containing amino acid sequence and 3D shapes of large biological macromolecules (such as proteins and nucleic acids)</li><li>- contains functions of proteins, their location within the cell and any molecules that they are known to interact with</li></ul>
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## 18.2 - enzymes

	<ul style="list-style-type: none"> <li>- biological catalysts that accelerate the rate of chemical reactions in cells</li> </ul>
role of enzymes	<p>enzymes can only catalyse one specific reaction or a reaction that involves a particular chemical bond or func. group</p> <ul style="list-style-type: none"> <li>- the specificity of enzymes</li> <li>- also more sensitive than inorganic catalysts to change in reaction conditions</li> </ul>
lock-and-key model of enzyme action	<p>catalytic activity depends on its overall 3D structure</p> <p>specific part of the enzyme molecule which a reactant can interact with is known as its active site</p> <ul style="list-style-type: none"> <li>- uniquely shaped, flexible hollow/cavity within the protein where the reaction occurs</li> <li>reactant molecules that binds with the active site = substrate</li> </ul> <p>'lock and key model' for catalytic action of an enzyme</p> <ul style="list-style-type: none"> <li>- substrate molecule fits into the enzyme, forming an enzyme-substrate complex</li> <li>- allows the enzyme to break the bonds in the substrate</li> </ul>
	<p>bonds are formed w/ the enzyme to form an enzyme - substrate complex</p> <p>enzyme</p> <p>substrate</p> <p>bonds break in the substrate</p> <p>new products are released</p> <p>enzyme is regenerated</p>

example - hydrolysis of proteins	<p>trypsin is an enzyme that break a protein chain next to a lysine or arginine amino acid (on the C-terminal side)</p> <ul style="list-style-type: none"> <li>- binds to the protein chain at that point and weakens that particular peptide bond, reducing the amount of energy required for it to react with a H<sub>2</sub>O molecule</li> </ul>
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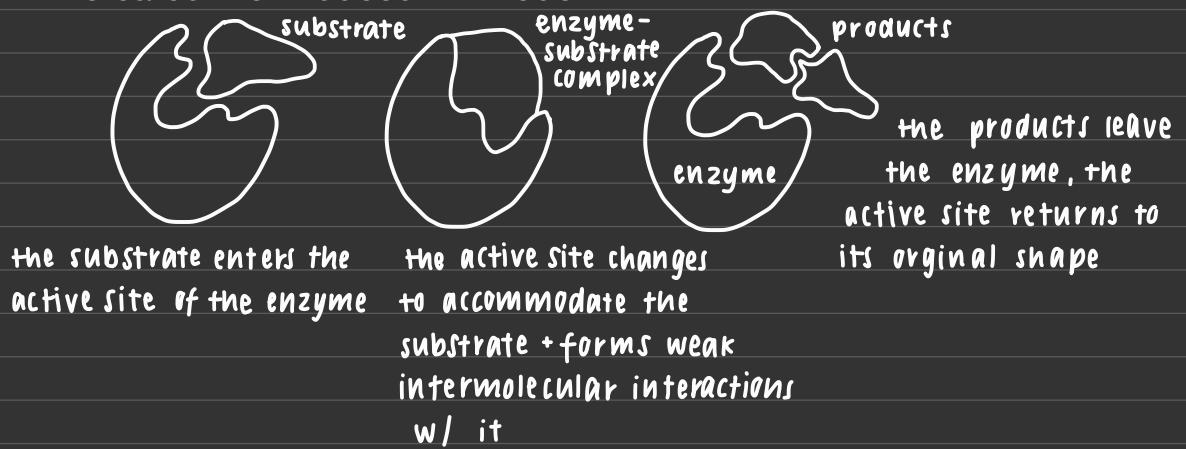


types of IMF between an enzyme and a substrate are the same as those that determine the tertiary structure of proteins

- determined by the side chains of the amino acids in the peptide sequence and can include H-bonds, ionic interactions, dipole-dipole attractions and dispersion forces
- amine groups form H-bonds with the active site of the trypsin enzyme, forming the enzyme-substrate complex

### induced fit model of enzyme action

- enzymes have flexible structures
- shape of the enzyme's active sit can be modified markedly by the binding of a substrate
- created the 'induced-fit' model



## 18.3 - enzymes: dependence on pH and temperature

dependence on pH	- operate effectively only in a narrow pH									
acid-base properties of enzymes	<ul style="list-style-type: none"> <li>- alpha-amino acids can form zwitterions</li> <li>- has both + and - charge within the molecule</li> <li>- high pH <math>\rightarrow</math> <math>-\text{NH}_3^+</math> acts as acid, donating proton <math>\rightarrow</math> <math>-\text{NH}_2</math> group</li> <li>- low pH <math>\rightarrow</math> <math>-\text{COO}^-</math> acts as base, accepting proton <math>\rightarrow</math> <math>-\text{COOH}</math></li> </ul> <div style="text-align: center; margin-top: 10px;"> <table border="0"> <tr> <td style="padding-right: 20px;">Low pH</td> <td style="padding-right: 20px;">Intermediate pH</td> <td style="padding-right: 20px;">High pH</td> </tr> <tr> <td><math>^*\text{H}_3\text{N}-\text{CH}(\text{R})-\text{COOH}</math></td> <td><math>\rightleftharpoons</math></td> <td><math>^*\text{H}_3\text{N}-\text{CH}(\text{R})-\text{COO}^-</math></td> </tr> <tr> <td>cation</td> <td>uncharged zwitterion</td> <td>anion</td> </tr> </table> </div>	Low pH	Intermediate pH	High pH	$^*\text{H}_3\text{N}-\text{CH}(\text{R})-\text{COOH}$	$\rightleftharpoons$	$^*\text{H}_3\text{N}-\text{CH}(\text{R})-\text{COO}^-$	cation	uncharged zwitterion	anion
Low pH	Intermediate pH	High pH								
$^*\text{H}_3\text{N}-\text{CH}(\text{R})-\text{COOH}$	$\rightleftharpoons$	$^*\text{H}_3\text{N}-\text{CH}(\text{R})-\text{COO}^-$								
cation	uncharged zwitterion	anion								
	<ul style="list-style-type: none"> <li>- ionisation of amino and carboxyl groups depends on pH</li> <li>- the change from neutral pH to an acidic pH of 3 = carboxylic acid on the side chain is not likely to ionise and therefore not carry the negative charge required for the ionic interaction to occur           <ul style="list-style-type: none"> <li>- opposite is true from neutral <math>\rightarrow</math> basic pH of 10</li> </ul> </li> <li>- higher pH, amino group on the other side of the chain wouldn't act as a base = remaining uncharged (unable to participate in ionic interaction)</li> </ul>									
	<p>changes in pH = large impact on the stability of enzyme structure      tertiary structure = disrupted = active sites change shape, enzyme activity decreases</p> <ul style="list-style-type: none"> <li>- very high/low pH can lose activity for most enzymes</li> </ul>									
	denaturation = permanent damage to the shape of an enzyme									
dependence on temperatures	<p>enzyme's optimum temperature</p> <ul style="list-style-type: none"> <li>- temps above/below = impaired function</li> </ul> <p>temp increase = increase KE of the molecules disrupts the structure</p> <ul style="list-style-type: none"> <li>- increased movement breaks IMF responsible for tertiary structure</li> <li>- active site no longer efficiently catalyses reaction</li> <li>- reaction rate decreases rapidly</li> </ul> <p>temp decrease = lower KE, less frequent and less energetic collisions</p> <ul style="list-style-type: none"> <li>- need flexibility so that the shape can change upon substrate binding</li> <li>- low temp = not flexible enough = cannot function properly</li> </ul>									
denaturation	<p>temp too high = increased KE of polypeptide chains = enzyme breaks some bonds between side chains</p> <ul style="list-style-type: none"> <li>- new bonds are formed</li> <li>- change in tertiary structure causes a change in the shape of the active site = loses catalytic activity = denatured</li> <li>- often irreversible</li> </ul>									

	<p>enzymes can be denatured by change in pH</p> <ul style="list-style-type: none"><li>- 3D structure is disrupted</li></ul> <p>- variations of pH and temp can permanently change tertiary structure of an enzyme</p> <ul style="list-style-type: none"><li>- the primary structure of the protein, cov bonded sequence of amino acids, remains intact</li></ul>
comparing denaturation with hydrolysis	<ul style="list-style-type: none"><li>- breakdown of proteins = hydrolysis</li><li>- products of hydrolysis = shorter polypeptide chains/individual amino acids<ul style="list-style-type: none"><li>- water is a reactant in this process, 1 H<sub>2</sub>O for every peptide bond broken</li></ul></li></ul>

## 18.4 - enzymes in industry

advantages and disadvantages	<p><u>advantages</u></p> <ul style="list-style-type: none"><li>- specific, catalyse only one reaction/type of reaction</li><li>- effective at biological temperatures + pH levels<ul style="list-style-type: none"><li>- saves energy and cost as high temp/pressure aren't required</li></ul></li><li>- not consumed in reaction, usable for a long period of time</li><li>- biodegradable = less pollution</li></ul> <p><u>disadvantages</u></p> <ul style="list-style-type: none"><li>- sensitive to changes in pH and temp. = tightly controlled reaction conditions</li><li>- certain chemicals can change the structure of enzymes = loss of function</li><li>- expensive to produce</li><li>- generally take place in (aq) solutions = often hard to separate products from the reaction mixture</li><li>- function optimally under biological conditions</li><li>- no need for high pressures/temps for fast RR</li></ul>
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have not included notes on production of ethanol - likely not necessary