CHEMISTRY 30
ULTRA-CONDENSED COURSE NOTES

THERMOCHEMISTRY SUMMARY

SKILLS TO MASTER

- Carrying out calorimetry calculations
- Relating enthalpy & molar enthalpy calculations
- Using standard enthalpies of formation
- Activation energy
- FORMULAS MUST BE MEMORIZED

Enthalpy change $\Delta H = n\Delta_r H$

ΔH = enthalpy change (kJ)

n = amount of substance (moles), from either:

- the balancing number from the equation.
- given in problem as moles of chemical statement.

$$n = \frac{m}{M} \quad \text{or} \quad n = CV$$

$\Delta_r H$ = molar enthalpy of reaction for specified chemical (kJ/mol)

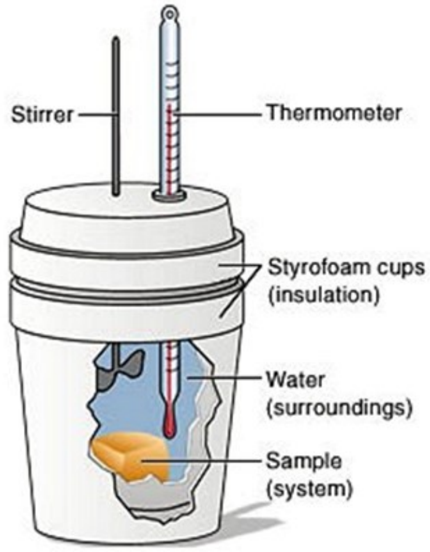
Subscripts can be used to denote the reaction type*:*

e.g. "r" for general reaction, "c" for combustion, "f" for formation.

Calorimetry

$$n\Delta_r H = mc\Delta t$$

where: n = moles of chemical specified (mol)
calculated either by n=CV for solutions or n=m/M for solids
$\Delta_r H$ = molar enthalpy of reaction (KJ/mol)
m = total (volume) mass of water in calorimeter (Kg)
c = 4.19 KJ/Kg °C
Δt = temperature change (°C) $t_i - t_f$



Standard Enthalpies of Formation

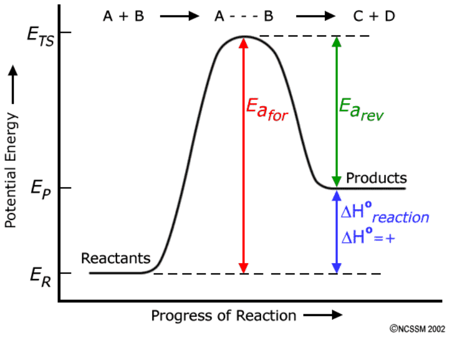
- Used to calculate enthalpy change for a chemical reaction

$$\Delta H = \Sigma n\Delta_f H_{\text{products}} - \Sigma n\Delta_f H_{\text{reactants}}$$

Where: ΔH = enthalpy change kJ
Σ means sum of
n = moles (mol)
$\Delta_r H$ = molar enthalpy of formation (kJ/mol) from data book pages 6 & 7

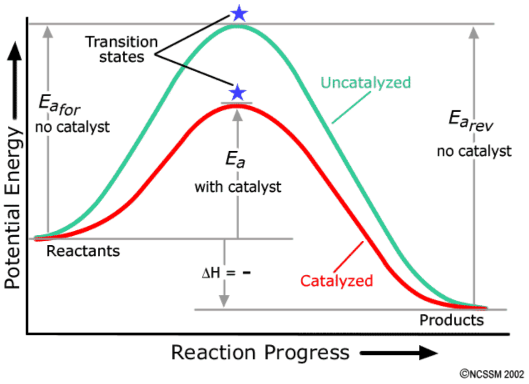
*Notes: $\Delta_r H$ of elements in their natural state is 0 kJ/mol. This is a set reference value. Combustion reactions in open systems produce $H_2O(g)$, while in closed systems $H_2O(l)$ is produced.

Endothermic Reaction

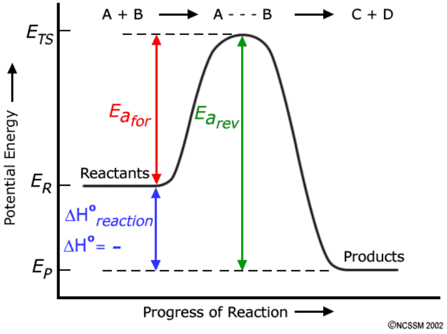


Activation Energy

- An energy barrier between reactants and products. This is the minimum amount of energy required to cause a chemical reaction to occur.
- The activation energy is the minimum amount of collision energy required to force both reactant molecules together into a single entity called an **activated complex**.
- **Catalysts** provide an alternative reaction pathway with a lower activation energy.
- Catalysts decrease time to reach equilibrium but do not change K_c or equilibrium position.



Exothermic Reaction

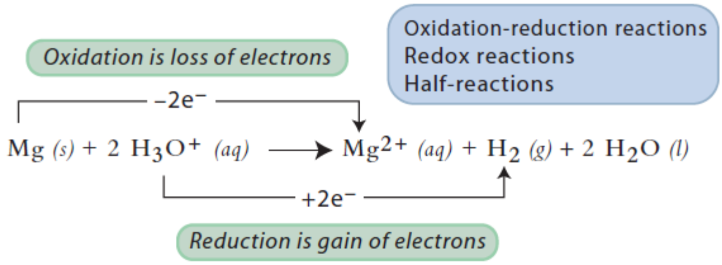


ELECTROCHEMISTRY SUMMARY

Skills to Master
1. oxidation numbers
2. Balancing redox reactions: “skeleton” & half-reaction method
3. Describing voltaic cells
4. Calculating cell potentials
5. Describing electrolytic cells
6. Cell stoichiometry
7. Corrosion protection

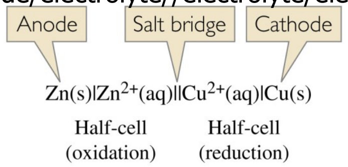
Recognizing Redox Reactions

- Oxidation is the loss of electrons (L.E.O. or O.I.L.)
- Reduction is the gain of electrons (G.E.R. or R.I.G.)
- Remember: **L.E.O. the lion says G.E.R. or OIL RIG**
- Reducing agents get oxidized
- Oxidizing agents get reduced

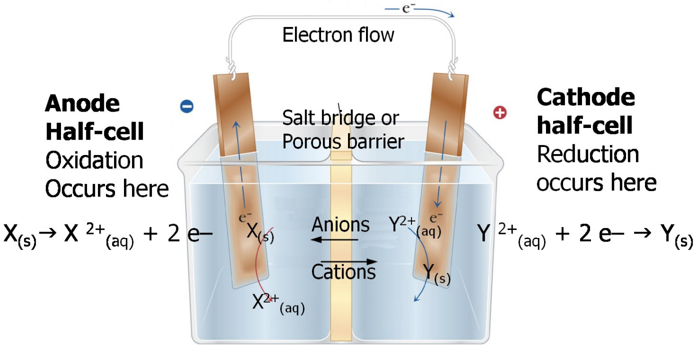


VOLTAIC CELLS

- Reduction occurs at the cathode (+ electrode)
- Oxidation occurs at the anode (– electrode)
- Electrons move from anode to cathode via the external wire.
- Anions move toward anode; Cations move toward cathode
- **Remember A or C:**
  - **A**node is **O**xidation **R**eduction is **C**athode
- Porous boundary or salt bridge is required to keep solutions separate but allow ion migration; prevents cell polarization.
- Net cell voltage (E^o_{net}) is positive
- Cell notation: electrode/electrolyte//electrolyte/electrode



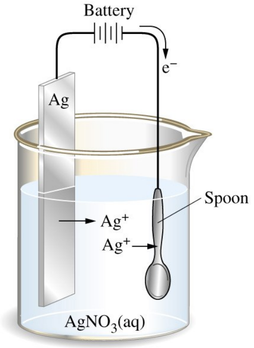
A voltaic cell



- Ions flow through the porous boundary to maintain electrical neutrality
- How to remember: A or C

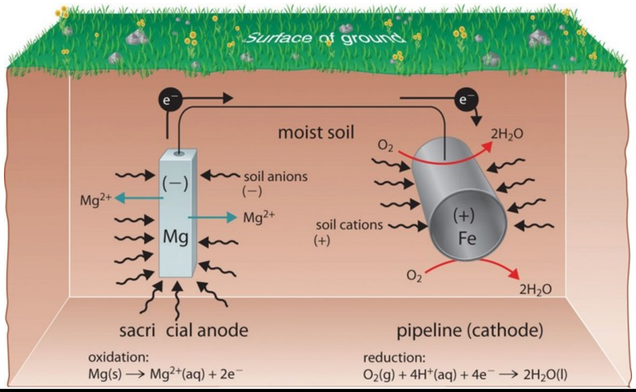
ELECTROLYTIC CELLS

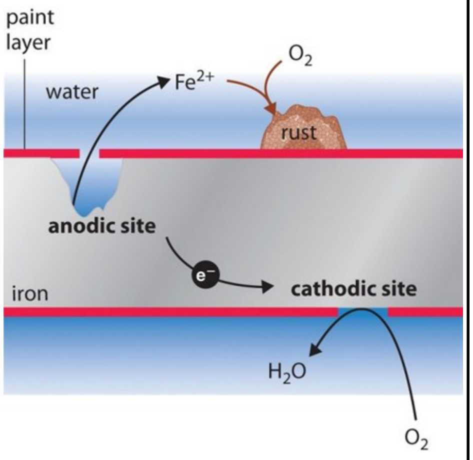
- **Same chemistry as the voltaic cell, *except***
  - Anode is + and cathode is -
  - No porous boundary/salt bridge needed since redox reaction is nonspontaneous.
  - Net cell voltage (E^o_{net}) is negative
- For electroplating, the object to be coated with metal must be the cathode.
- Electrorefining: producing pure elements using electrolysis.
  - Weak reducing agents (nonspontaneous with water) can be made in an aqueous cell
  - Strong reducing agents (spontaneous reaction with water) made in molten cell.
- **Chloride anomaly:** Cl_2 (g) is produced when electrolyzing an aqueous ionic chloride compound.



CORROSION PROTECTION

- Methods to prevent corrosion (unwanted spontaneous redox reaction)
  - Paint the object or coat with nonreactive (inert) coating like plastic.
  - Cathodic protection—**impressed current**. Connect object to a power supply. Forces object to be a cathode.
  - Cathodic protection—**sacrificial anode.** Connect a stronger reducing agent metal to the object. S.R.A. is an anode and the object is the cathode.





EQUILIBRIA & LE CHATELIER'S SUMMARY

SKILLS TO MASTER

1. Writing equilibrium-law expressions.
2. Calculating equilibrium values at equilibrium
3. Calculating equilibrium concentrations from initial. (I.C.E. tables)
4. Le Chatelier's principle

EQUILIBRIUM LAW (expressions & constants)

- Equilibrium reactions must show evidence of reversibility
- Macroscopic properties (temp, pressure, pH, colour) are constant.
- Equilibrium can only be reached in a closed or isolated system.
- Equilibrium can be approached from either direction.
- Equilibrium constants relate the extent of the equilibrium
    - Kc>1 products favoured
    - Kc<1 reactants favoured
    - Kc=1 neither reactants nor products favoured.

EQUILIBRIUM EXPRESSION

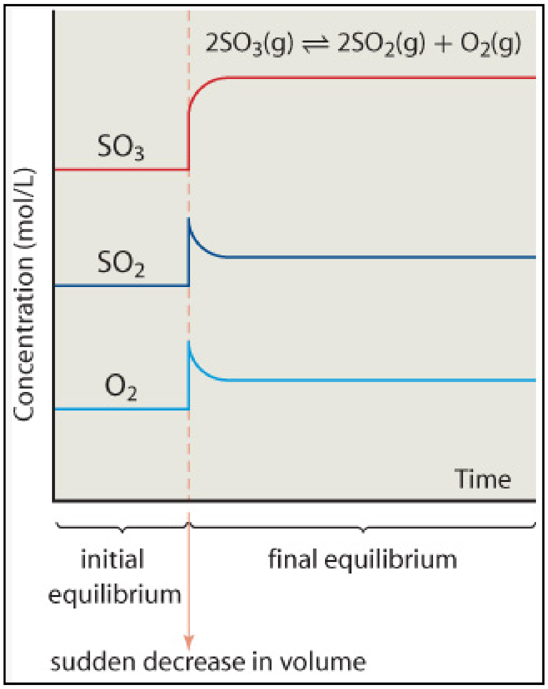
$$aA + bB \rightleftharpoons \quad dD$$

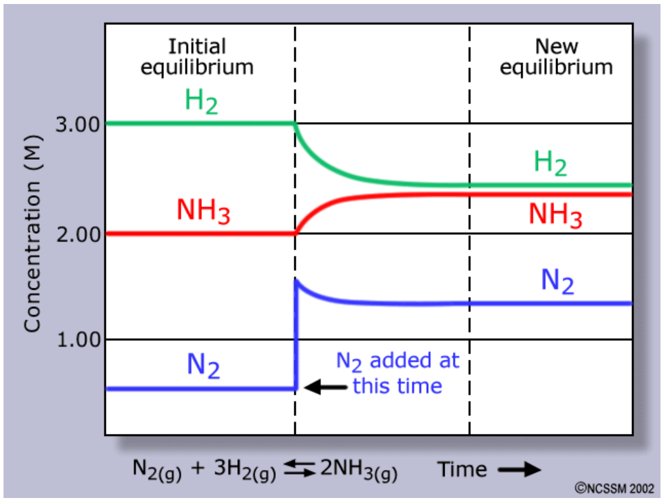
$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

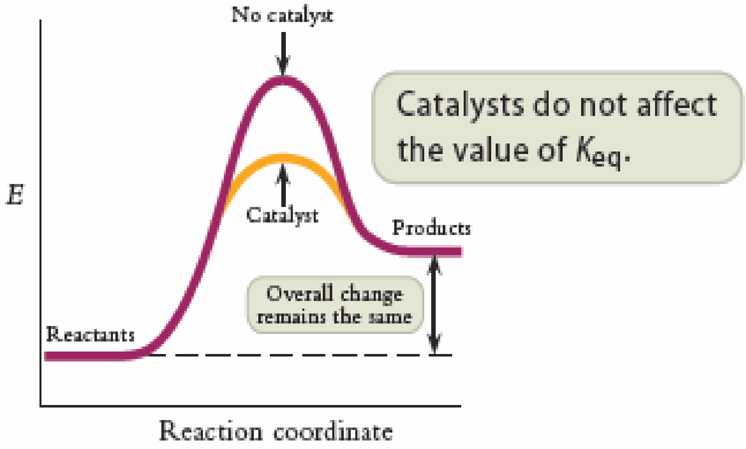
- Pure solids and solvents do not appear in the K_c expression.
- Do not include H_2O in aqueous systems.

LE CHATELIER'S PRINCIPLE—EQUILIBRIUM SHIFTS

- A system in equilibrium tends to respond so as to relieve the effect of any stress upon the system.
- A stress is anything that causes a change in the equilibrium concentrations.
- Temperature change is the only stress that can change the value of an equilibrium constant, K_c
- Catalysts increase reaction rate (decrease time to achieve equilibrium) but do not affect the equilibrium position and K_c value.
- Catalysts decrease the activation energy.
- General rules for applied stresses:
    - Remove product or add reactant—shift right
    - Remove reactant or add product—shift left
    - Decrease volume—shift to side with fewer gas moles.







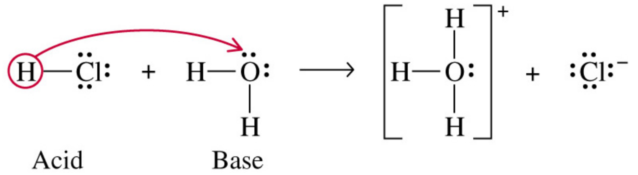
BRONSTED-LOWRY ACID-BASE SUMMARY

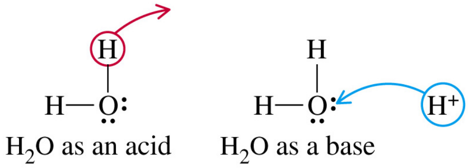
SKILLS TO MASTER

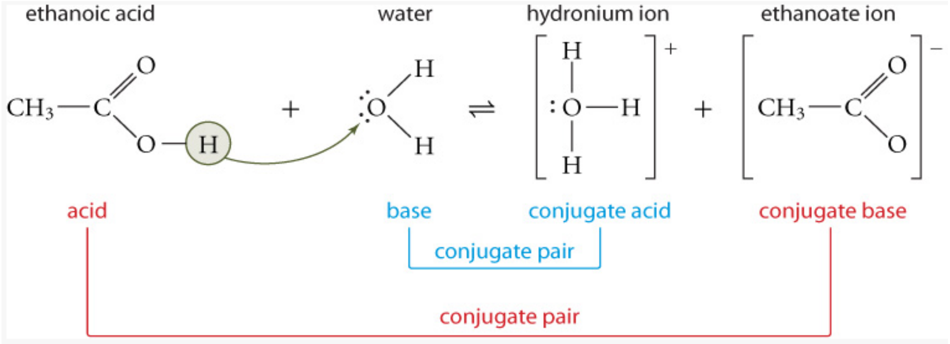
1. Bronsted-lowry acid-base theory.
2. pH & pOH calculations
3. K_a K_b K_w calculations
4. pH titration curves
5. Buffer solutions

BRONSTED-LOWRY THEORY

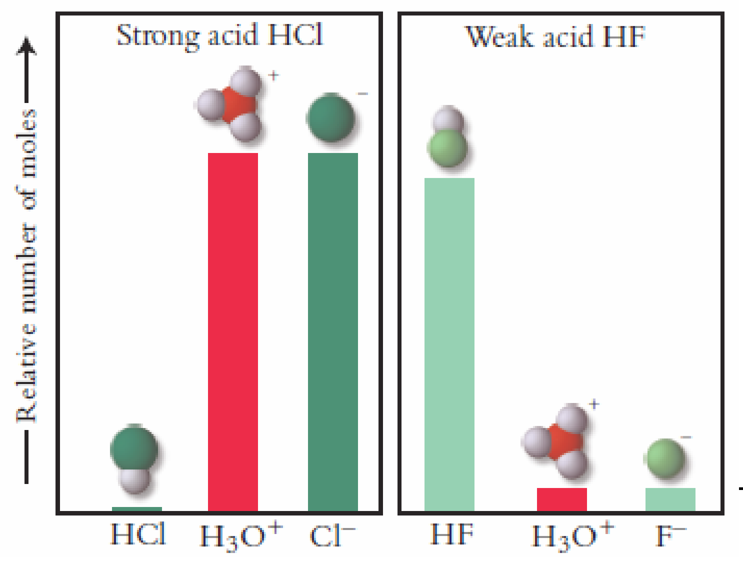
- **Acids donate protons**
- **Bases accept protons**
- **Amphiprotic** species can act as either acids or bases.
- Every Bronsted-Lowry acid-base reaction consists of two acid-base conjugate pairs.
- A **conjugate pair** consists of two species that **differ only by one H**.

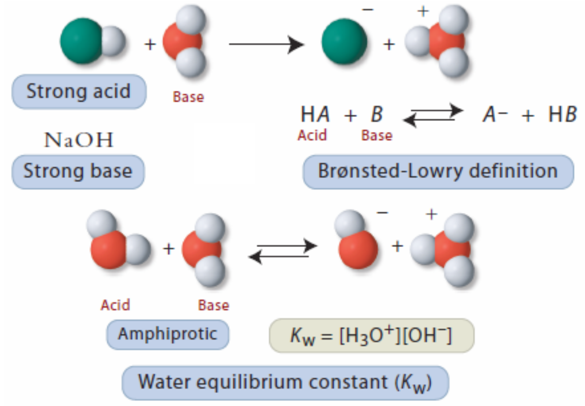






- **Monoprotic** acids can only donate one proton (H^+); **polyprotic** can donate two or more.
- Monoprotic bases can only accept one proton; polyprotic bases can accept more than one
- **Hydronium ion H_3O^+ is the strongest acid present in water**.
- **Strong acids completely ionize (K_c>1)** into hydronium ion H_3O^+
- **Weak acids only partially ionize (K_c<1).**





MATHEMATICAL RELATIONSHIPS

- Equilibrium constant for acids $K_a=\frac{[H_3O^+][A^{1-}]}{[HA]}$ which simplifies to $K_a=\frac{[H_3O^+]^2}{[HA]}$
- Equilibrium constant for bases $K_b=\frac{[HB][OH^{1-}]}{[B^{1-}]}$ which simplifies to $K_b=\frac{[OH^{1-}]^2}{[B^{1-}]}$

- $Kw=[H_3O^+][OH^{1-}]$
- $Kw=K_a x K_b$
- $pH= -\log[H_3O^+]$ and $[H_3O^+]=10^{-pH}$
- $pOH= -\log[OH^{1-}]$ and $[OH^{1-}]=10^{-pOH}$
- pH + pOH = 14.00

Bronsted-Lowry pH calculations

Strong acid

Since strong acids ionize completely to H_3O^+ pH can be directly calculated from acid concentration:

$$pH = -\log [H_3O^+]$$

Strong base

Since strong bases dissociate completely to OH^- pH cannot be directly calculated. You calculate pOH first using

$$pOH = -\log [OH^-]$$

then use

$$pH = 14.00 - pOH$$

Weak Acid

Weak acids only partially ionize with water to produce some H_3O^+ thus you must first determine the $[H_3O^+]$ by using an equilibrium expression:

First use $K_a = \frac{[H_3O^+]^2}{[HA]}$ rearranged to $[H_3O^+] = \sqrt{K_a \bullet}$

then use $pH = -\log [H_3O^+]$

Weak base

Weak bases only partially ionize with water to produce some OH^- thus you must first determine the $[OH^-]$ by using an equilibrium expression:

First find the K_b of the weak base using $K_w = K_a K_b$ rearranged to

$$K_b = \frac{K_w}{K_{a \text{ of conjugate acid}}}$$

then use $K_b = \frac{[OH^-]^2}{[A^-]}$ rearranged to $[OH^-] = \sqrt{K_b \bullet}$

next use $pOH = -\log [OH^-]$

and finally $pH = 14.00 - pOH$

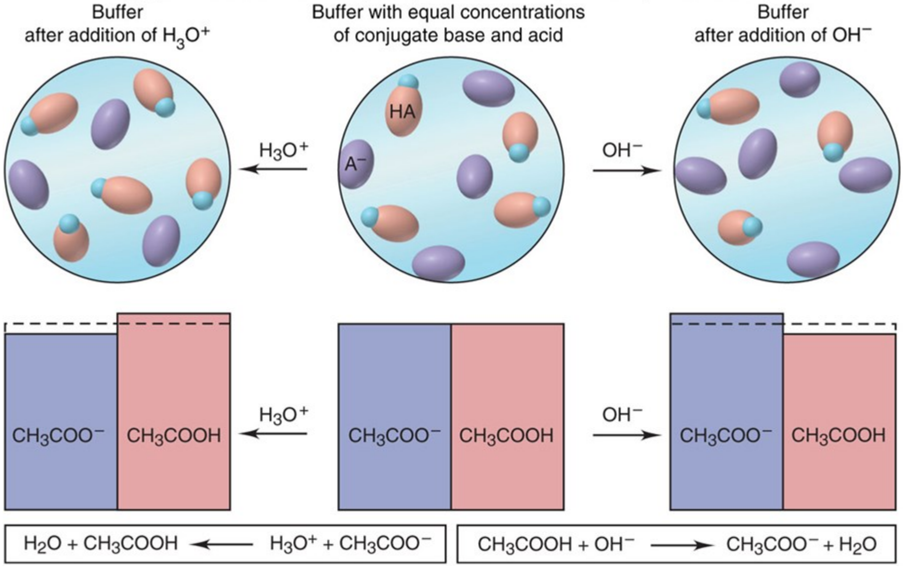
BUFFERS

Solutions that resist changes in pH when either small amounts of strong acid or strong base are added.

Buffer solutions contain a weak acid and its conjugate base in the same concentrations:

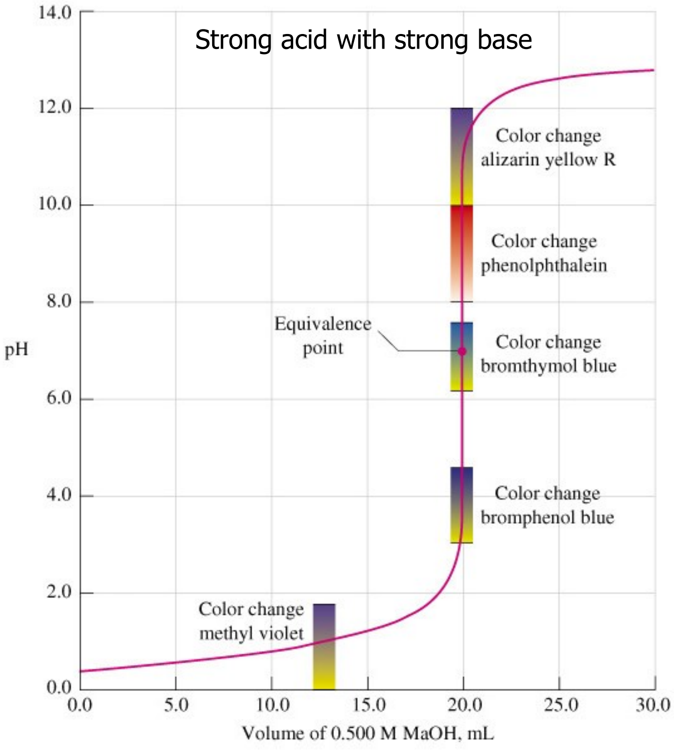
$$[HA] = [A^-]$$

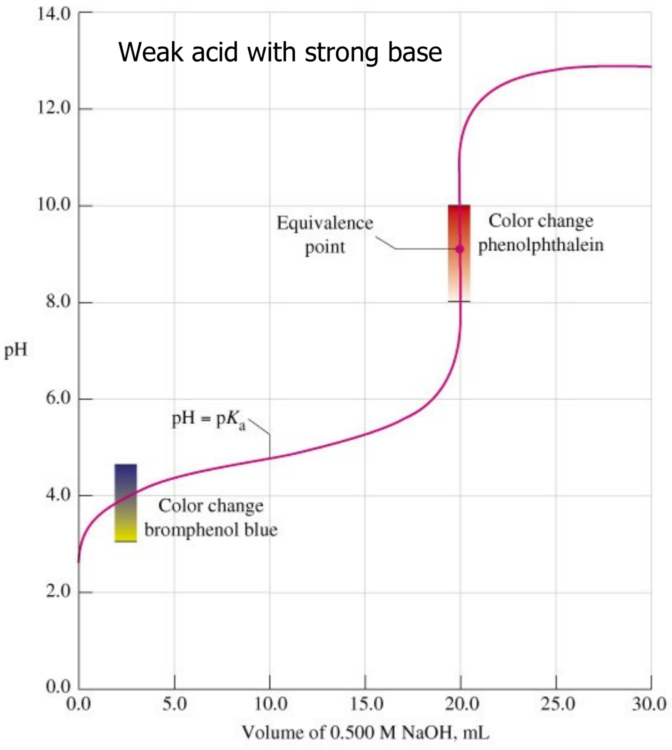
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

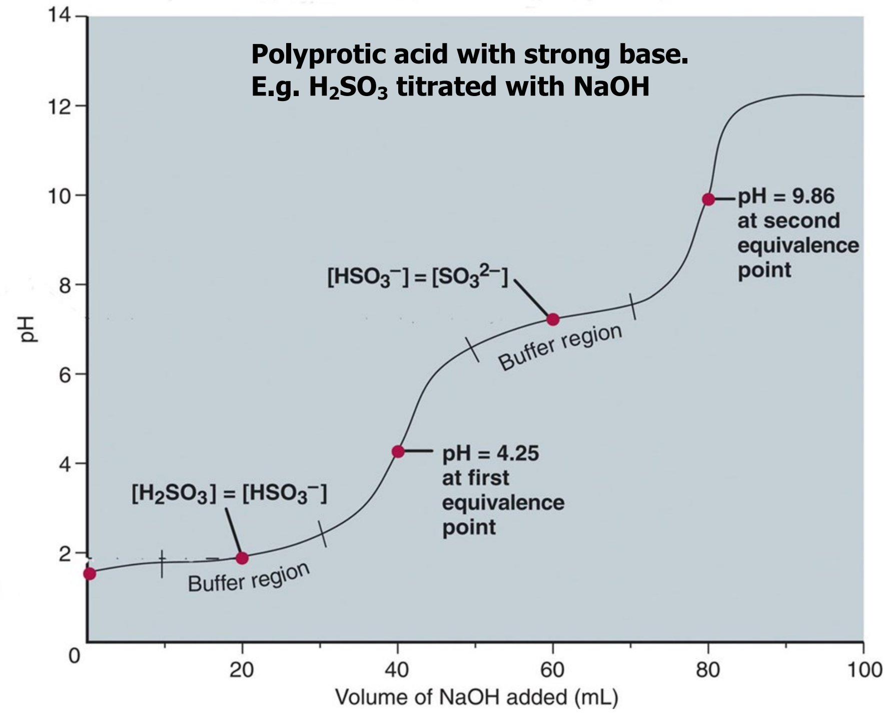


pH TITRATION CURVES

The best indicators to use will change colour **at or near** the equivalence point



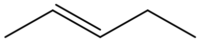
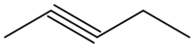
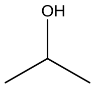
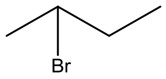
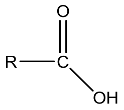
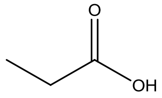
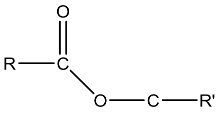
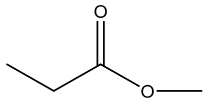




ORGANIC CHEMISTRY SUMMARY

Skills to Master

- Naming organic compounds.
- Identifying functional groups.
- Identifying organic chemical reactions.
- Predicting organic reaction products.
- Identifying polymers & monomers.

Family Name	Suffix or prefix	Functional group	Example	Generic formula
alkene	-ene	$-C=C-$		C_nH_{2n}
alkyne	-yne	$-C\equiv C-$		C_nH_{2n-2}
alcohol	-ol	-OH called a hydroxyl group	 propan-2-ol	R-OH
alkyl halide	fluoro chloro bromo iodo	F- Cl- Br- I-	 2-bromobutane	R-X where X is a halogen.
carboxylic acid	-oic acid		 propanoic acid	R-COOH
ester	-oate		 methylpropanoate	R-COOC-R′

Addition Reactions (start with a double or triple bond)

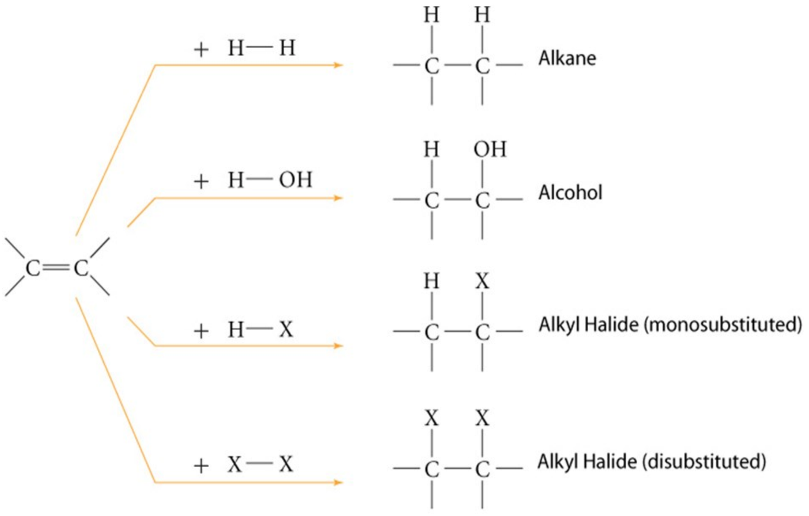
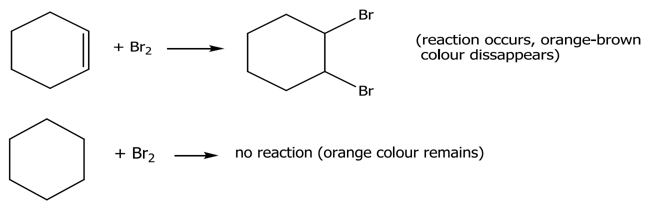


Figure 15.2 In each addition reaction shown here, the electrons in the second bond are rearranged and form bonds with the two additional atoms.

Bromine test or $KMnO_4$ test for double & triple bonds (unsaturated compounds)

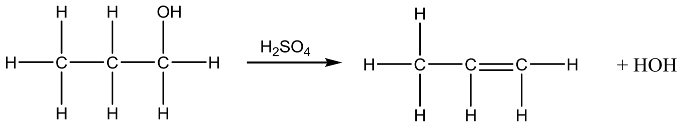
- The addition of elemental bromine (Br_2), which has an orange-brown colour, or the purple coloured $KMnO_4$, to a hydrocarbon can be used to test for the presence of double or triple bonds.
- Alkenes and alkynes will react with Br_2 (& $KMnO_4$) , remaining clear.
- Alkanes and benzene do not react with Br_2 or $KMnO_4$, so the solution has an orange-brown colour due to the presence of Br_2 molecules (or is purple due to the presence of unreacted MnO_4^{1-} ion)
- Example:



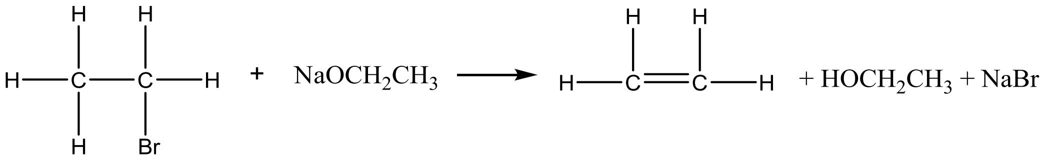
Elimination Reactions

- removal of a functional group resulting in the formation of a double bond.

Alcohol elimination—alcohol + strong acid → alkene + water



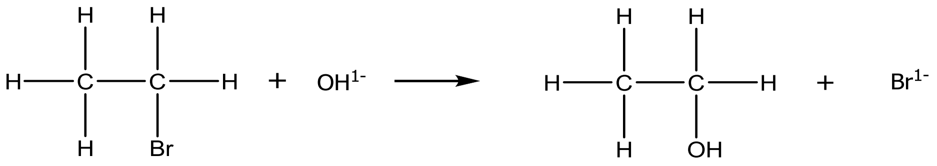
Alkyl halide elimination—alkyl halide + sodium ethoxide →alkene + ethanol + sodium halide salt



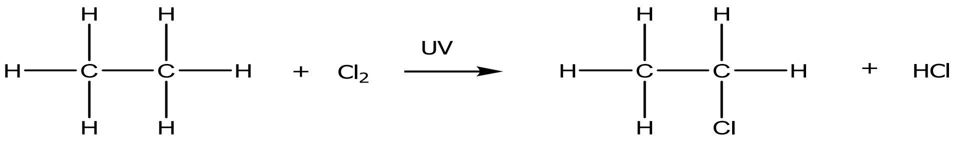
Substitution Reactions– occur with alkanes only

- A hydrogen atom or functional group (e.g. Cl atom) is replaced with a different functional group)

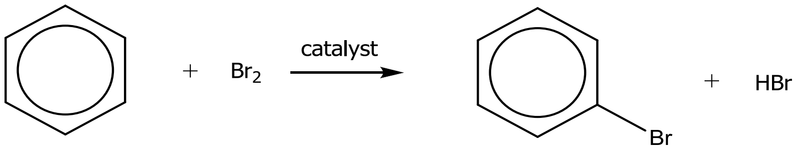
Alkyl halides can undergo a substitution reaction with hydroxide ion (OH^{1-}) to produce an alcohol.



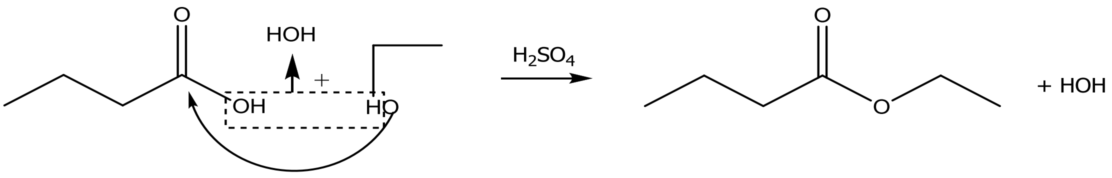
Alkanes can undergo substitution with a halogen to produce an alkyl halide. This requires the energy from UV light.



Benzene behaves like an alkane and can undergo substitution with a halogen molecule to produce an alkyl halide and a small acid molecule.

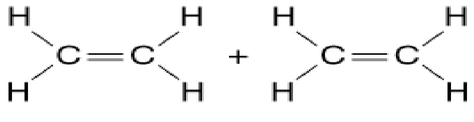


Esterification (a type of condensation reaction)-An alcohol combines with a carboxylic acid to produce an ester.

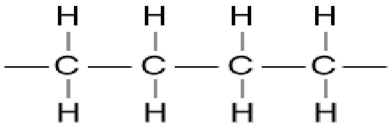


Addition polymers

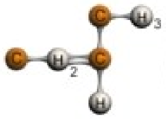
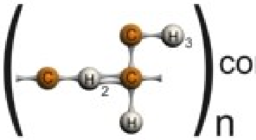
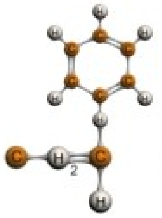
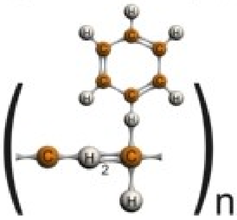
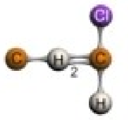
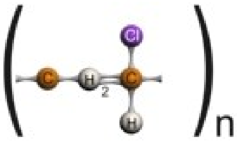
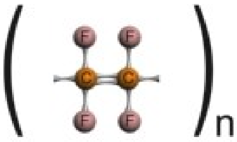
- **monomer must be an alkene or alkyne**
- The double bond is lost/ the triple bond gets reduced to a double bond
- Different functional groups give different properties.



ethene + ethene



polythene

Name	Monomer	Structur	Uses
Polypropylene			containers, fibers, film, carpet
Polystyrene			insulation, styrofoam
Polyvinyl chloride (PVC)			plumbing, vinyl leather
Polyfluoroethene (Teflon)			cookware, bearings

Condensation polymers– **monomer(s) must be bifunctional** (a functional group on both ends of the carbon parent chain).