

### Transition metal complexes

Complex	Few drops NaOH/NH <sub>3</sub>	Excess NaOH	Excess NH <sub>3</sub>
pale green [Fe(H <sub>2</sub> O) <sub>6</sub> ] <sup>3+</sup>	dirty green Fe(OH) <sub>2</sub>	-	-
green/violet [Cr(H <sub>2</sub> O) <sub>6</sub> ] <sup>3+</sup>	pale green Cr(OH) <sub>3</sub>	deep green soln. [Cr(OH) <sub>6</sub> ] <sup>3+</sup>	violet soln. [Cr(NH <sub>3</sub> ) <sub>6</sub> ] <sup>3+</sup>
yellow [Fe(H <sub>2</sub> O) <sub>6</sub> ] <sup>3+</sup>	brown Fe(OH) <sub>2</sub>	-	-
blue [Cu(H <sub>2</sub> O) <sub>6</sub> ] <sup>2+</sup>	pale blue Cu(OH) <sub>2</sub>	-	deep blue soln. [Cu(NH <sub>3</sub> ) <sub>4</sub> (H <sub>2</sub> O) <sub>2</sub> ] <sup>2+</sup>
pale pink [Mn(H <sub>2</sub> O) <sub>6</sub> ] <sup>2+</sup>	light brown Mn(OH) <sub>2</sub>	-	-

### Test for halide ions

Halide ion	Adding HNO <sub>3</sub> and AgNO <sub>3</sub>	Adding NH <sub>3</sub>
Chloride	White ppt	Dissolves in dilute
Bromide	Cream ppt	Dissolves in conc.
Iodide	Yellow ppt	Doesn't dissolve

HNO<sub>3</sub> added first to the halide, then AgNO<sub>3</sub>. This forms a ppt, from which the colour can be used to identify the halide. NH<sub>3</sub> is then added if necessary; in dilute ammonia, e.g: only chloride ions dissolves, whereas iodide ions don't dissolve at all.

### Organic tests (AS)

Alcohols	Add K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> /H <sup>+</sup>	Orange to green for 1 <sup>st</sup> and 2 <sup>nd</sup> alcohols
Alkenes	Add bromine water	Orange to colourless
Haloalkanes	Dissolve in ethanol, add water, then do the halide test	

### Organic tests (A-level)

Aldehyde/-ketone	Add 2,4-DNP (Brady's reagent)	Orange ppt forms
Aldehyde	Add Tollen's reagent	Silver mirror forms
	Add Fehling's reagent	Red ppt forms
Carboxylic acid	Add carbonate (same as AS)	CO <sub>2</sub> forms
	Add PCl <sub>5</sub>	Steamy white fumes produced
Benzene	Add bromine water (room temp)	no reaction.
	Combustion	Burns with sooty flame

### Radical Substitution

Conditions	UV light
Bond fission	homolytic (2 radicals formed from covalent bond)
Organic product	haloalkane
Limitations	further substitution is almost impossible to control, products have to be separated by fractional distillation or chromatography
INITIATION	Cl <sub>2</sub> → 2Cl*
PROPAGATION	CH <sub>4</sub> + Cl* → *CH <sub>3</sub> + HCl *CH <sub>3</sub> + Cl <sub>2</sub> → CH <sub>3</sub> Cl + Cl*
TERMINATION	2Cl* → Cl <sub>2</sub> *CH <sub>3</sub> + *CH <sub>3</sub> → C <sub>2</sub> H <sub>6</sub> *CH <sub>3</sub> + Cl* → CH <sub>3</sub> Cl

### Electrophilic Substitution (nitration of benzene)

Reagents/conditions	conc. HNO <sub>3</sub> , conc. H <sub>2</sub> SO <sub>4</sub> , 50°C
Electrophile	NO <sub>2</sub> <sup>+</sup>
Organic product	nitrobenzene
Gen. of electrophile	HNO <sub>3</sub> + H <sub>2</sub> SO <sub>4</sub> → NO <sub>2</sub> <sup>+</sup> + HSO <sub>4</sub> <sup>-</sup> + H <sub>2</sub> O
Regen. of catalyst	HSO <sub>4</sub> <sup>-</sup> + H <sup>+</sup> → H <sub>2</sub> SO <sub>4</sub>

### Electrophilic Sub. (chlorination of benzene)

Reagents/conditions	Cl <sub>2</sub> , AlCl <sub>3</sub>
Electrophile	Cl <sup>+</sup>
Organic product	chlorobenzene
Gen. of electrophile	AlCl <sub>3</sub> + Cl <sub>2</sub> → AlCl <sub>4</sub> <sup>+</sup> + Cl <sup>+</sup>
Regen. of catalyst	AlCl <sub>4</sub> <sup>+</sup> + H <sup>+</sup> → AlCl <sub>3</sub> + HCl

### Electrophilic Sub. (acylation of benzene)

Reagents/conditions	CH <sub>3</sub> COCl, AlCl <sub>3</sub>
Electrophile	CH <sub>3</sub> CO <sup>+</sup>
Organic product	phenyl ethanone
Gen. of electrophile	AlCl <sub>3</sub> + CH <sub>3</sub> COCl → AlCl <sub>4</sub> <sup>-</sup> + CH <sub>3</sub> CO <sup>+</sup>
Regen. of catalyst	AlCl <sub>4</sub> <sup>-</sup> + H <sup>+</sup> → AlCl <sub>3</sub> + HCl

### Electrophilic Sub. (alkylation of benzene)

Reagents/conditions	CH <sub>3</sub> Cl, AlCl <sub>3</sub>
Electrophile	CH <sub>3</sub> <sup>+</sup>
Organic product	methyl benzene
Gen. of electrophile	CH <sub>3</sub> Cl + AlCl <sub>3</sub> → CH <sub>3</sub> <sup>+</sup> + AlCl <sub>4</sub> <sup>-</sup>
Regen. of catalyst	AlCl <sub>4</sub> <sup>-</sup> + H <sup>+</sup> → AlCl <sub>3</sub> + HCl

### Electrophilic Sub. (bromination of benzene)

Reagents/conditions	Br <sub>2</sub> , AlBr <sub>3</sub>
Electrophile	Br <sup>+</sup>
Organic product	bromobenzene
Gen. of electrophile	AlBr <sub>3</sub> + Br <sub>2</sub> → AlBr <sub>4</sub> <sup>-</sup> + Br <sup>+</sup>
Regen. of catalyst	AlBr <sub>4</sub> <sup>-</sup> + H <sup>+</sup> → AlBr <sub>3</sub> + HBr

### Ammonium, NH<sub>4</sub><sup>+</sup>

Add NaOH to test for NH<sub>3</sub> Red litmus paper turns blue if present

### Carbonate, CO<sub>3</sub><sup>2-</sup>

Add HCl to carbonate solution CO<sub>2</sub> forms. Turns limewater cloudy

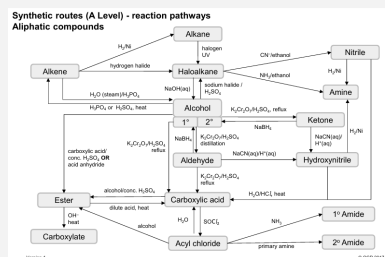
### Sulphate, SO<sub>4</sub><sup>2-</sup>

Add BaCl<sub>2</sub> White ppt forms if present (BaSO<sub>4</sub>)

### Rate equations

Rate =  $k[A]^m[B]^n$   
 $k = Ae^{-E_a/RT}$   
 $\ln k = -E_a/RT + \ln A$   
 $k$  = rate constant  
 $[A]$  = concentration of A  
 $[B]$  = concentration of B  
 $m$  = order wrt A  
 $n$  = order wrt B  
 $A$  = Arrhenius pre-exponential factor  
 $e$  = exponential  
 $E_a$  = activation energy (kJmol<sup>-1</sup>)  
 $T$  = temperature, K  
 $R$  = gas constant (8.314 JK<sup>-1</sup>mol<sup>-1</sup>)  
 $\ln$  = natural log

### Reaction pathways (aliphatic compounds)



Conditions and reactants/reagents shown

### Electrophilic Addition (alkenes)

Electrophile electron pair acceptor  
 Carbocation positive ion with electron deficient carbon  
 Bond fission heterolytic (cation and anion formed from covalent bond)  
 Organic product haloalkane

! Curly arrows show movement of an electron

### Nucleophilic Substitution (haloalkanes)

Reaction	Reagent/conditions	Nucleophile	Organic product
Hydrolysis (NaOH)	hot NaOH(aq)	OH <sup>-</sup>	alcohol
NH <sub>3</sub>	ethanolic NH <sub>3</sub>	-	amine
KCN	ethanolic KCN	-	nitrile

Nucleophile: electron pair donor

Substitution: when an atom or group of atoms is replaced by another

Ethanolic: derived from or containing ethanol

### Nucleophilic Addition (carbonyl compounds)

#### Reaction with NaBH<sub>4</sub>

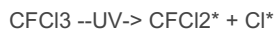
Reagents/conditions	NaBH <sub>4</sub> , warmed
Reaction type	reduction
Nucleophile	H <sup>-</sup>
Organic product	alcohol

#### Reaction with HCN

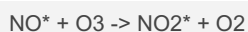
Reagents/conditions	HCN
Nucleophile	CN <sup>-</sup>
Organic product	hydroxynitrile

### Free radical sub. of ozone

#### Depletion 1\*



#### Depletion 2\*\*



\*due to chlorine radicals from CFC's

\*\*due to nitrogen oxide from aircraft engines and lightning

