

### 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 <sup>•</sup>                                                                                               |
| PROPAGATION     | CH <sub>4</sub> + Cl <sup>•</sup> → •CH <sub>3</sub> + HCl                                                                       |
|                 | •CH <sub>3</sub> + Cl <sub>2</sub> → CH <sub>3</sub> Cl + Cl <sup>•</sup>                                                        |
| TERMINATION     | 2Cl <sup>•</sup> → 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 <sup>•</sup> → 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 |
|-------------------------------|-----------------------------------------------|

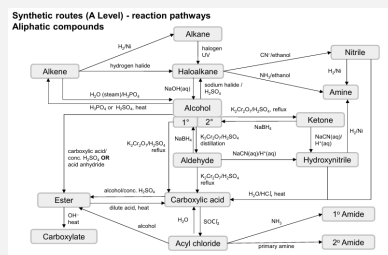
### Sulphate, SO<sub>4</sub><sup>2-</sup>

|                       |                                                 |
|-----------------------|-------------------------------------------------|
| 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>

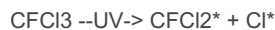
|                     |                            |
|---------------------|----------------------------|
| Reagents/conditions | NaBH <sub>4</sub> , warmed |
| Reaction type       | reduction                  |
| Nucleophile         | H <sup>-</sup>             |
| Organic product     | alcohol    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

#### 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

