## A. DEFINITION

Photosynthesis is:

The production of **carbon compounds** in **cells** using **light energy**

carbon dioxide + water + light energy ⟶ glucose + oxygen

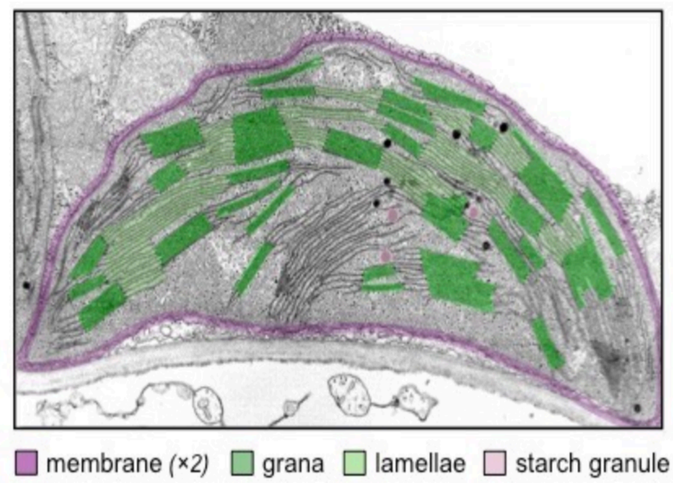
## B. HOW CARBOHYDRATES ARE PRODUCED

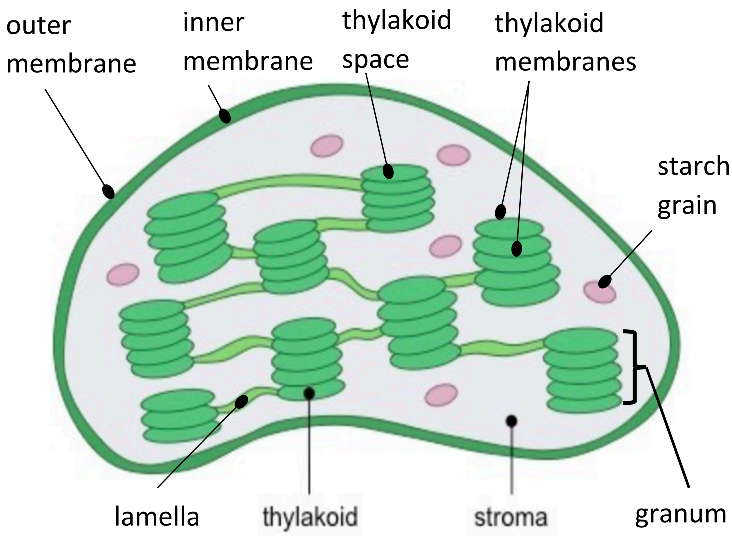
- **light energy** is converted to **chemical energy**
- **some** of the **energy** is used to produce **ATP**;
- **ATP**/energy is needed to produce **glucose**;
- **chlorophyll** absorbs **light**;
- **chlorophyll** absorbs **red** and **blue light AND** reflects **green light**;
- . **light** is used for **photolysis**/to **split water molecules**;
- **electrons/H** from **water** are used to **reduce** compounds;
- **$CO_2$** is absorbed/used/**reduced** to produce **carbohydrates**;
- plants absorb/**fix $CO_2$** using **rubisco** (enzyme);
- **electrons** provide **energy** to **fix $CO_2$**;
- . **glucose** can be converted to **other carbohydrates/starch**/**cellulose**;
- produces **oxygen** (as a waste product);

## C. CHLOROPLAST STRUCTURE

**ELECTRON MICROGRAPH**

**DIAGRAM**



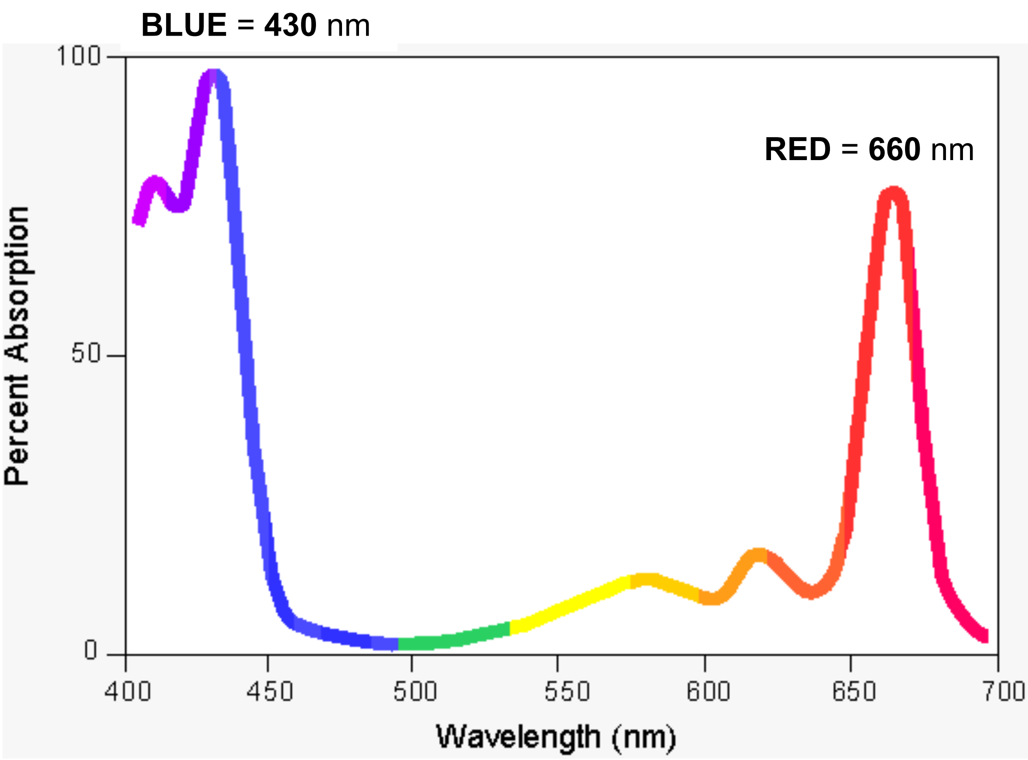

- Feel free to **also add** many **70S ribosomes** and **circular DNA** to the diagram
- **Thylakoids** contain **lots** of **chlorophyll** and **stacked** for maximum **light absorption**
- A **stack** of **thylakoids** is called a **granum**
- **Grana** are **connected** by structures called **lamellae**
- The **stroma** contains **enzymes** (e.g. **rubisco**) for **$CO_2$ fixation** to **glucose**

## D. TYPES OF SPECTRA

- Light is **absorbed** by **photosynthetic pigments** such as **chlorophyll a** and **chlorophyll b**.

- **Different photosynthetic pigments** absorb **different amounts** of **different wavelengths** of **light**.

### Absorption Spectrum



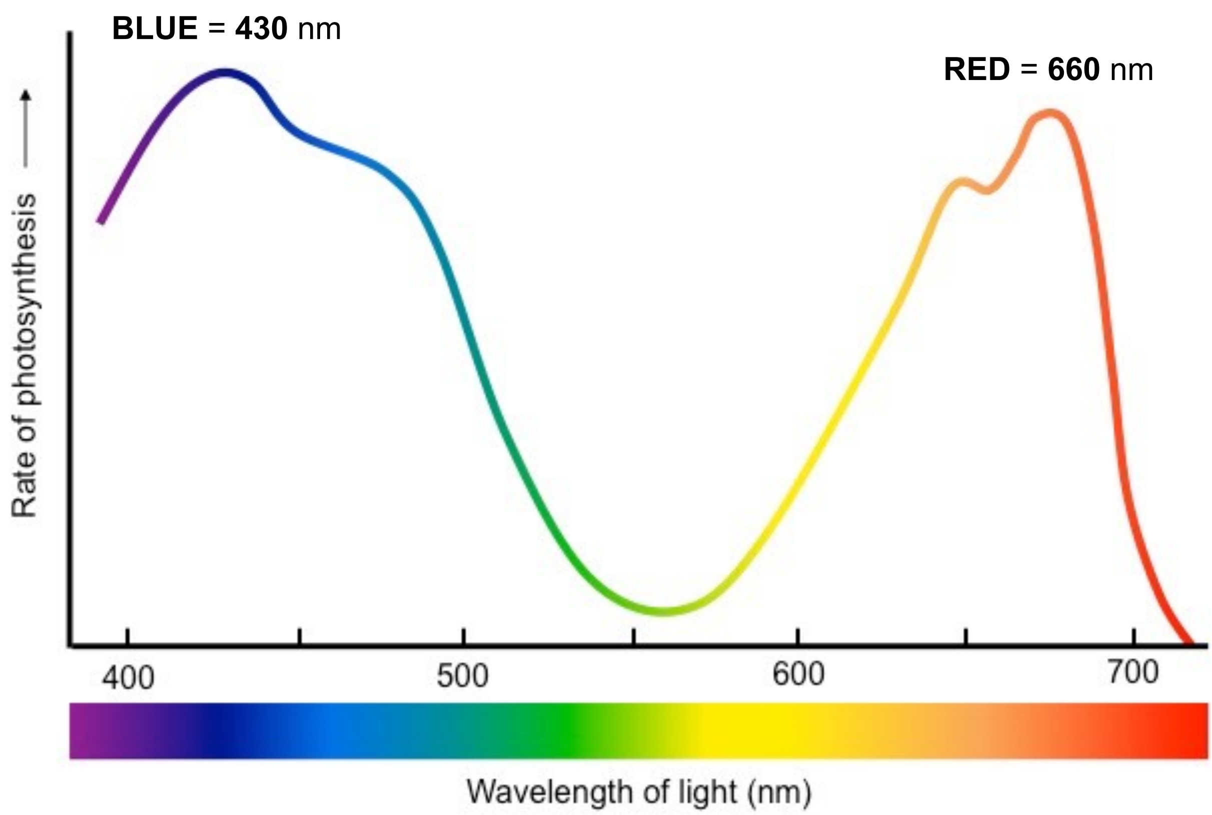

- Shows the **wavelengths** of **light absorbed** by each **pigment** (e.g. chlorophyll).

- Visible light has a range of wavelengths with **violet** the **shortest wavelength** and **red** the **longest wavelength**.

- Chlorophyll **absorbs red** and **blue light most effectively** and **reflects green light** more than other colours. This explain why leaves look green.

## Action Spectrum

- Shows the **rate of photosynthesis** at **each wavelength** of **light**.



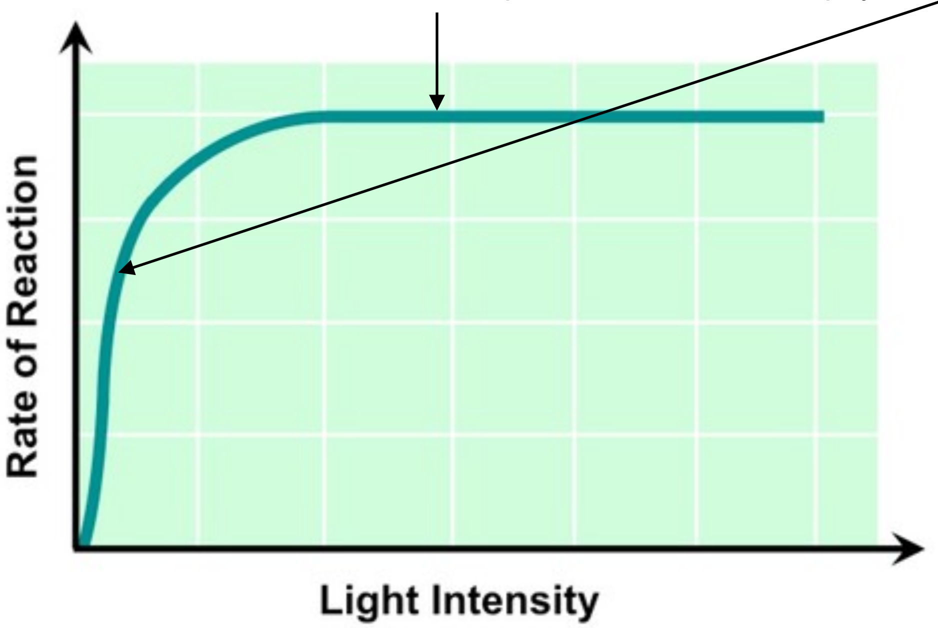

- It is **mainly blue** and **red light** that are **used** in **photosynthesis**.
- Notice that the **rate of photosynthesis** for **green light** is **not** at **zero**.
- It is **accessory photosynthetic pigments** (not chlorophyll) that **use** the **small amount** of **green light**.
- Examples of **accessory pigments** include **beta-carotene** and **xanthophyll**.

**You are expected to be able to draw these spectra**

## E. EFFECT OF LIMITING FACTORS

- A limiting factor **prevents** the **rate of photosynthesis** from **increasing** when it is in **short supply**.

### Light intensity



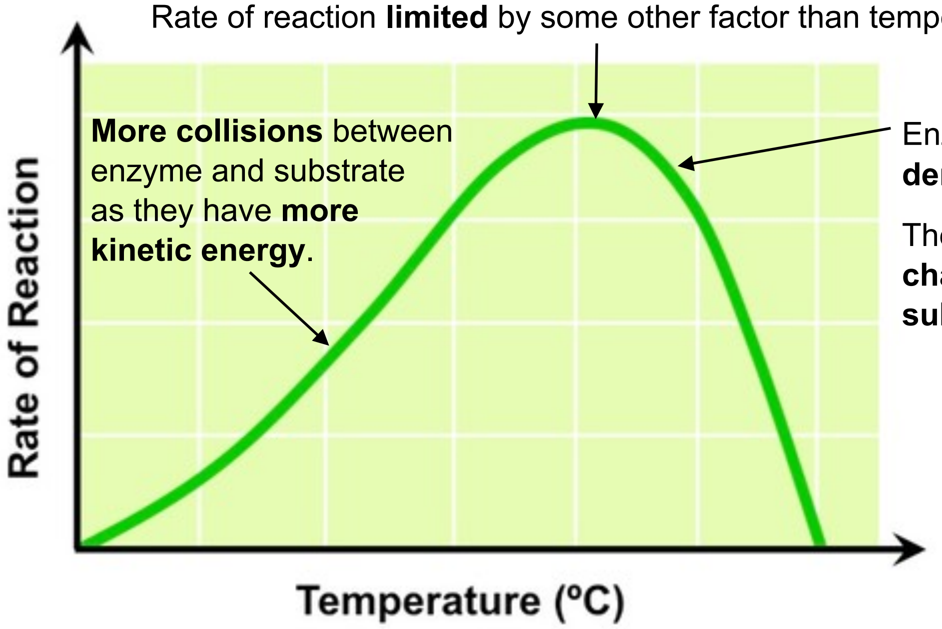

Rate of reaction is **limited** by the **light intensity**.

This is because **light** is **needed** to **split water** into **oxygen** and **electrons**.

The **electrons** provide the **energy** to convert **carbon dioxide** into **carbohydrates**, such as **glucose**.

### Temperature

- Photosynthesis is controlled by **enzymes**. The enzyme **rubisco fixes $CO_2$** to produce glucose.
- Temperature is the **limiting factor** at both **low** and **high** temperatures.

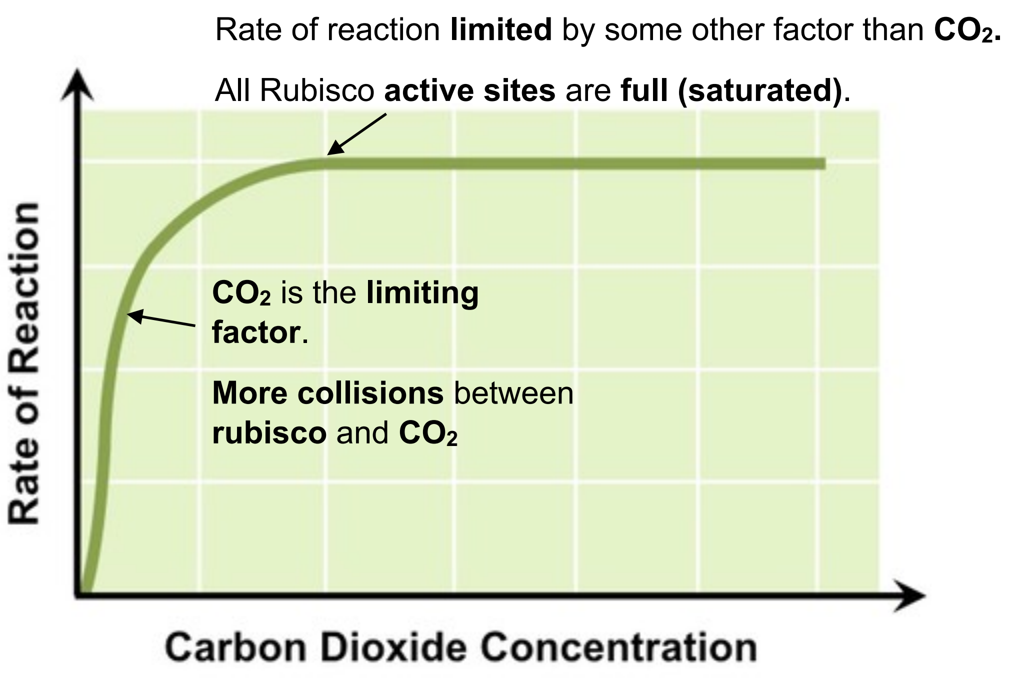



Enzymes can be **denatured**.

Their **active site changes shape** so the **substrate cannot fit** in.

**Carbon dioxide**

- The enzyme **rubisco fixes $CO_2$** to produce **glucose**.



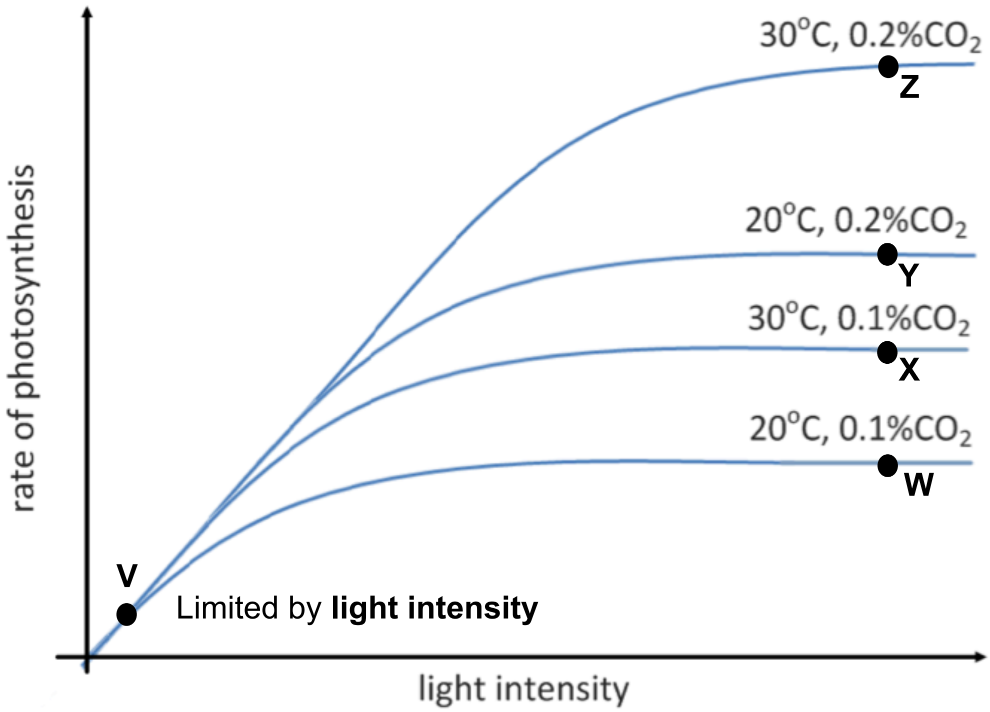

## D. INVESTIGATING LIMITING FACTORS

- **Independent variable** is the factor that is **changed** each time.
- **Dependent variable** is the factor that is **measured**.
- **Control variables** are the factors that are **kept the same** each time.

| Limiting factor | Method of varying it | Method of controlling it | Suggested range |
|---|---|---|---|
| **Light** | Move **lamp different distances** from the plant | Keep the lamp at a fixed distance from the plant | 4, 5, 7, 10 and 14 cm and no light |
| **Temperature** | Use a **thermostatically controlled water bath** | Set the thermostat on the water bath at 25°C and keep it there throughout the experiment | 5°C to 45°C<br>in 5°C or 10°C intervals |
| **Carbon dioxide** | Add different amounts of **sodium hydrogen carbonate** ($NaHCO_3$) to increase the $CO_2$ concentration | Add enough sodium hydrogen carbonate to make sure that it does not run out | 0 – 50 mmol $dm^{-3}$<br>in 10mmol $dm^{-3}$ intervals |

## F. PREDICTING THE LIMITING FACTOR FROM A GRAPH

- Much easier if you look at the **curves** in **pairs**.
- It must be concluded from **what is shown in the graph**, rather than what you know about photosynthesis.
- The graph shows the effects of **light intensity** on the **rate of photosynthesis** at two different **temperatures** and two different **$CO_2$ concentrations**.
- It **is** possible to work out which is the **limiting factor** from the graph.




- At **V**, it is limited by **light intensity** for all curves.
- **W** and **X** show it is limited by **temperature**.
- **W** and **Y** show it is limited by **$CO_2$ concentration**.
- **Y** and **Z** show it is limited by **temperature**.
- **X** and **Z** show it is limited by **$CO_2$ concentration**.

## G. SEPARATING PHOTOSYNTHETIC PIGMENTS BY CHROMATOGRAPHY

- A **concentrated spot** of **pigment** is **spotted** onto **chromatography paper**.

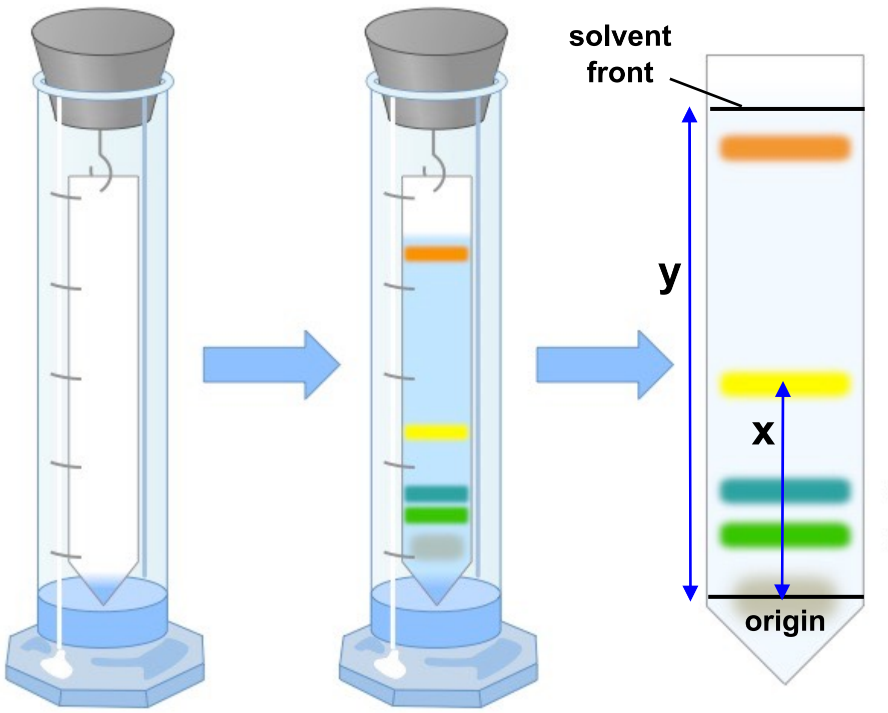
- In a **sealed** container, the **solvent evaporates** and **diffuses up** the paper. It moves **from** its **origin** and **ends** at the **solvent front**.

- The **different components** of the **mixture** travel at **different speeds**, causing them to separate.

- **Different substances** will **separate** at **different distances** as they have **different solubilities** in the solvent.

- The **Rf value** of each substance is then **calculated** using the formula:

$$\textbf{Rf} = \frac{\text{distance moved by } \textbf{substance}}{\text{distance moved by } \textbf{solvent}} = \frac{\textbf{x}}{\textbf{y}}$$




| Pigment | Rf value |
|---|---|
| Carotene | 0.95 |
| Xanthophyll | 0.71 |
| Chlorophyll a | 0.65 |
| Chlorophyll b | 0.45 |
| *Leaf stain* | |

- This **value** is then **compared** to **known Rf values** in a **table** or **book** for **this given solvent**.

- This allows the **unknown substance** to be **identified**.

- For example, the **Rf table** will only name the pigment **xanthophyll** as having an **Rf value** of **0.71** with this solvent.

**ORGANIC** solvents, such as **ETHANOL, PROPANONE** or **ACETONE** are used

- Paper chromatography **can** be used to separate photosynthetic pigments but **thin layer chromatography** gives **better results**.