

Jockey Club STEAM Education Resources Sharing Scheme

Photos in a Coffee Can

Laboratory Manual and Worksheets

Name: _____

Class: _____

School: _____

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Contents

Background.....	1
Unit 1 – Capturing the Light.....	2
1. Introduction.....	2
2. Summary of Unit 1	2
2.1 Reflection and refraction of light	2
2.2 Dual nature of light	5
2.3 Film camera.....	5
3. References	6
Student Worksheet	7
Unit 2 – The Chemistry of Image Capturing.....	11
1. Introduction.....	11
2. Summary of Unit 2	11
2.1 The structure of a film	11
2.2 Camera film.....	12
3. References	13
Student Worksheet	14
Unit 3 – The Birth of a Photograph	18
1. Introduction.....	18
2. Summary of Unit 3	18
2.1 Film development process.....	18
2.2 Converting negative image to positive image	20
2.3 Photography skills	20
3. References	22
Student Worksheet	23
Unit 4 – I Am a Film Developer	27
1. Introduction.....	27
2. Summary of Unit 4	27
3. Duration.....	27
4. Objective.....	27
5. Equipments and materials	27
6. References	29
Student Worksheet	30

Background

Introduction

“Photos in a Coffee Can” is one of the core modules in the scheme to enhance students’ interest in learning STEAM via a project which integrates KLAs from different subjects.

This module consists of four units covering science, technology, engineering, arts and mathematics:

- ◆ Unit 1 – Capturing the Light
- ◆ Unit 2 – The Chemistry of Image Capturing
- ◆ Unit 3 – The Birth of a Photograph
- ◆ Unit 4 – I Am a Film Developer

By applying different knowledge and techniques in STEAM, the four units combined to form a single project of photo-taking and film development, which would help you study and investigate their physical and chemical knowledge and theories.

Learning outcomes

Upon the completion of the module, you should be able to:

- ◆ Understand the physics of light, such as reflection, refraction and nature of light
- ◆ Comprehend chemical theories such as acid-base, redox reactions and functional groups of organic compounds
- ◆ Explain the working principles of photography by applying the physical theories learnt
- ◆ List out the chemical compounds used for film development
- ◆ Explain the working principles of film development by applying the chemical theories learnt
- ◆ Develop a film

Unit 1 – Capturing the Light

1. Introduction

Although cameras such as single-lens reflex type can be very delicate and expensive, the working principle of photography, in fact, is not difficult. The most important part of a film camera is the lens. Light from the object will pass through the lenses and is reflected and refracted. It is then focused on the roll film and initiates a series of reactions on it in order to record down the object.

A simple structure of a film camera will be introduced in this unit. Different lenses used in a film camera and how light from the object is reflected and refracted to the eye and the film will be introduced and illustrated.

This unit would familiarise students with the physics of light and the simple mechanism of photo-taking necessary for you to understand Unit 2.

2. Summary of Unit 1

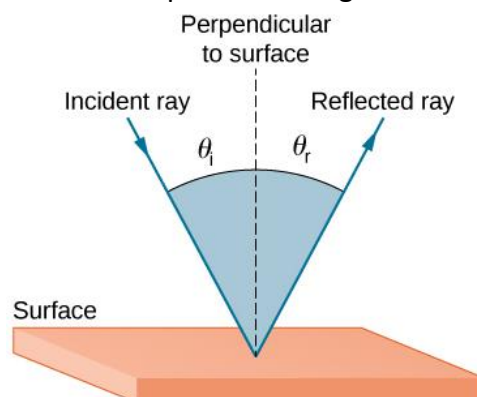
2.1 Reflection and refraction of light

Why we can see:

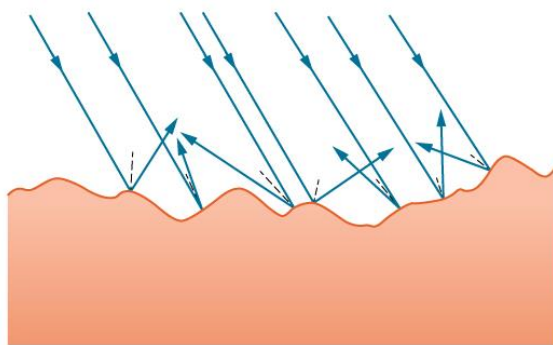
- ◆ Luminous objects
 - They can be seen because they emit their own light
- ◆ Non-luminous objects
 - They can be seen when they reflect the light from the light sources into your eyes

The laws of light reflection:

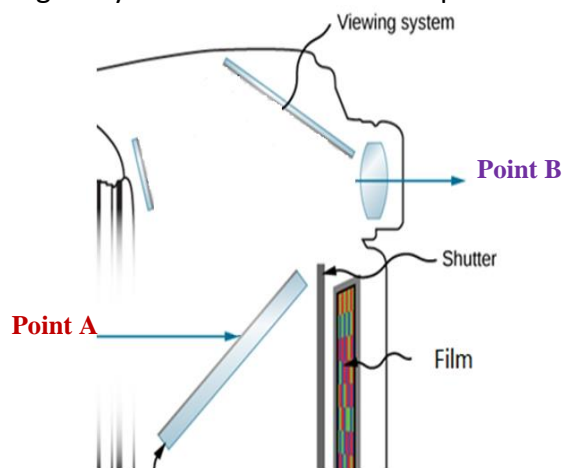
- ◆ The reflection of light obeys the laws of reflection
 1. The incident ray, reflected ray and normal lie on the same plane
 2. The angle of reflection is equal to the angle of incidence



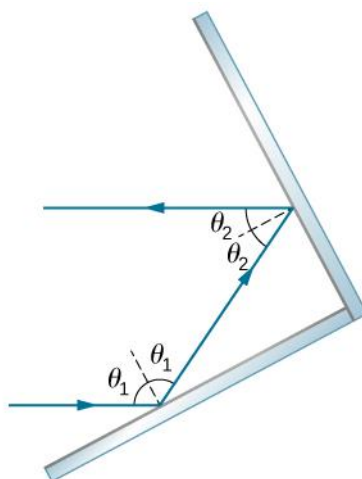
- ◆ On a rough surface:
 1. Diffuse reflection occurs on a rough surface
 2. Parallel incident light rays are reflected in different directions
 3. Obey the laws of reflection



- ◆ Try to draw the light ray which is reflected from point A and finally goes to point B

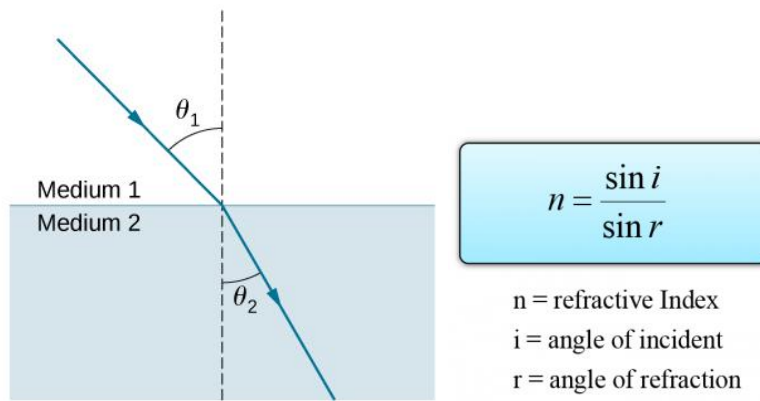


- ◆ Try to explain why the incoming light ray and the outgoing light ray in the following graph are always parallel to each other



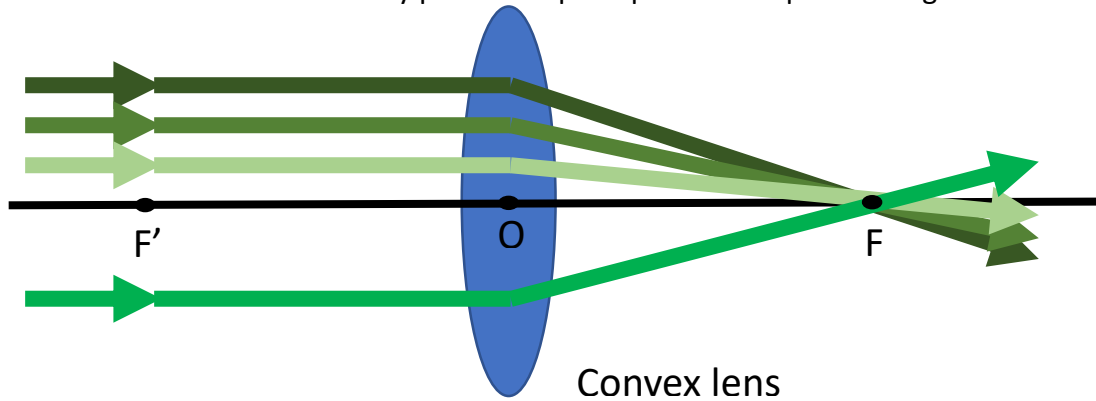
The laws of light refraction:

- ◆ When a light ray enters a medium from another
- ◆ The refraction of light is due to the difference in its travelling speeds in different media
 1. Speed of light in air: $\sim 3 \times 10^8$ m/s
 2. Speed of light in water: $\sim 2.25 \times 10^8$ m/s
- ◆ Laws of refraction:
 1. The incident ray, refracted ray and normal all lie on the same plane
 2. The angle of refraction can be calculated by using Snell's law:

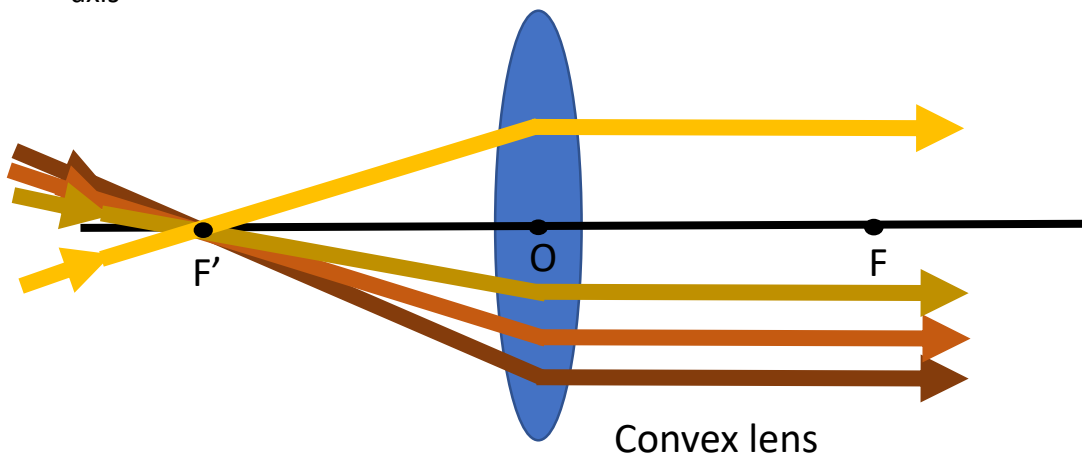


Refraction of light by using convex lens:

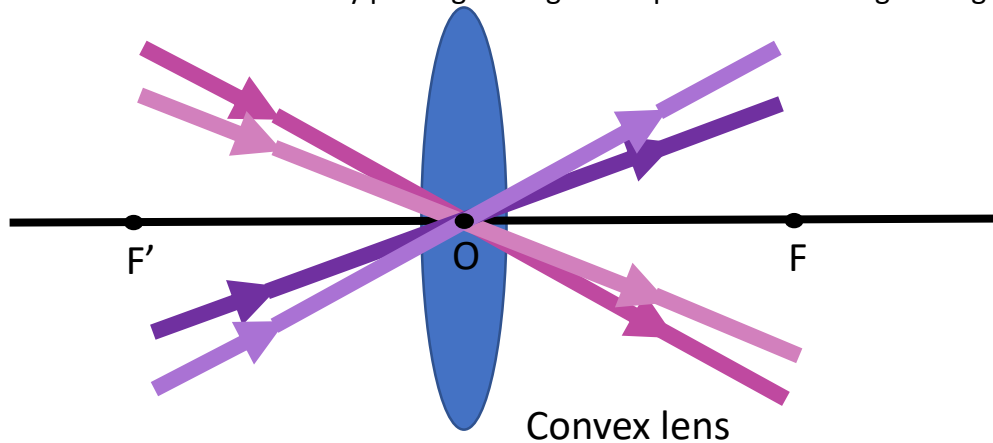
- ◆ Laws of refraction #1: Ray parallel to principal axis will pass through focus



- ◆ Laws of refraction #2: Ray passing through focus will become parallel to the principal axis



- ◆ Laws of refraction #3: Ray passing through the optical centre will go straight



2.2 Dual nature of light

- ◆ Light is a wave because:
 1. Light can be reflected
 2. Light can be refracted
 3. Light can also be diffracted (diffraction) and interfered with (interference)
- ◆ Light is a particle called photon because:
 1. Light can be used to kick out electrons from a metal surface
 2. And it is called the photoelectric effect

2.3 Film camera

Film camera:

- ◆ A tool for light or image capturing
- ◆ By making use of the physics of light (reflection and refraction)
- ◆ Light rays can be directed into our eyes or the film
- ◆ By aperture, lenses and mirror

The structure of a simple film camera:

- ◆ Aperture:
 - An “opening” to allow light to enter the camera
 - The amount of light entering the camera can be adjusted by controlling the size of the aperture
- ◆ The lenses:
 - Direct and focus the light to the film by the refraction of light
 - Both concave and convex lenses are used
 - The size of the image is affected by the focal length of the lenses used
- ◆ Viewfinder (viewing system):
 - A hole or a lens at the back of the camera
 - Allows the photographer to preview the image before it is captured by the film
- ◆ Flip-up mirror:
 - A movable mirror
 - Reflects the light from the object to the viewfinder

- It will be flipped up so that the light from the object can reach the film when you take a photo
- ◆ Shutter:
 - A “gate” is a piece of opaque metal or plastic
 - Prevents light from reaching the film
 - The speed of the shutter release can be controlled
- ◆ How the light from the target is captured by the film? (Between F' and $2F'$)
 - The light from the target is refracted and focused on the film
 - The image on the film is inverted and enlarged
- ◆ When the target is placed at $2F'$
 - The image is not focused on the film but in front of it
 - We need a lens that has a longer focal length (weaker refractive power)
- ◆ Convex lens and refractive power

Thinner convex lens	Thicker convex lens
Refracts light to a lesser extent	Refracts light to a greater extent
The refracted light reaches the principal axis later	The refracted light reaches the principal axis earlier
The focal length is bigger	The focal length is smaller
Weaker refractive power	Stronger refractive power

3. References

Charles S. and Johnson, JR., Science for the Curious Photographer, second edition, Routledge, 2010

Nichole Marie Witten, The Chemistry of Photography, University of South Carolina Scholar Commons, Spring 5-5-2016.

Photographic films, University of Houston College of Technology, Page 1-8

Photos in a Coffee Can
Unit 1 – Capturing the Light

Student Worksheet

1) Which of the following is a luminous object?

- A. Sun
- B. Moon
- C. A4 paper
- D. Rubbish bin

2) Which of the following is a non-luminous object?

- A. Sun
- B. Lamp
- C. Smart phone
- D. Smart phone case

3) Which of the following statements about the laws of light reflection are correct?

- (1) The incident ray, reflected ray and normal lie on the same plane
- (2) The incident ray, reflected ray and normal lie on two different planes
- (3) The angle of reflection is equal to the angle of incidence
- (4) The angle of reflection is smaller than the angle of incidence

- A. (1) and (2)
- B. (2) and (3)
- C. (3) and (4)
- D. (1) and (3)

4) Which of the following statements about the light refraction is/are correct?

- (1) It happens when light ray enters a medium from another
- (2) It happens because of changing the travelling speed of light
- (3) The travelling speed of light in air is lower than that in water.
- (4) The angle of refraction is always equal to the angle of incidence

- A. (1) only
- B. (2) only
- C. (1) and (2)
- D. (3) and (4)

5) Which of the following statements about the laws of light refraction is/are correct?

- (1) The incident ray, refracted ray and normal all lie on the same plane
- (2) It follows the Snell's law
- (3) The incident ray, refracted ray and normal lie on two different planes
- (4) The angle of refraction is always equal to the angle of incidence

- A. (1) only
- B. (2) only
- C. (1) and (2)
- D. (3) and (4)

6) Which of the following statements about the laws of light refraction by using convex lens is/are correct?

- (1) Ray parallel to principal axis will pass through focus
- (2) Ray passing through focus will become parallel to principal axis
- (3) Ray passing through optical center will go straight
- (4) Ray passing through optical center will be totally reflected

- A. (1) only
- B. (2) only
- C. (1) and (2) and (3)
- D. (2) and (3) and (4)

7) Light is considered as a wave because:

- (1) Light can be reflected
- (2) Light can be refracted
- (3) Light can be diffracted and interfered
- (4) Light cannot be diffracted and interfered

- A. (1) and (2)
- B. (1) and (3)
- C. (1) and (2) and (3)
- D. (2) and (3) and (4)

8) Light is considered as a particle because of:

- A. Reflection
- B. Refraction
- C. Diffraction
- D. The photoelectric effect

9) Film camera consists of:

- (1) Aperture
- (2) Lenses
- (3) Mirror
- (4) Film

- A. (1) and (2)
- B. (1) and (3)
- C. (1) and (2) and (3)
- D. (1) and (2) and (3) and (4)

10) Which of the following statements about “aperture” are correct?

- (1) It allows light to enter the camera
- (2) The size of it can be controlled
- (3) It refracts the light
- (4) It reflects the light

- A. (1) and (2)
- B. (2) and (3)
- C. (3) and (4)
- D. (1) and (2) and (4)

11) Which of the following statements about “lenses” are correct?

- (1) Only convex lens is used
- (2) Both concave and convex lenses are used
- (3) They direct and focus the light to the film by the refraction of light
- (4) They direct and focus the light to the film by the reflection of light

- A. (1) and (2)
- B. (2) and (3)
- C. (3) and (4)
- D. (1) and (2) and (4)

12) Which of the following statements about “viewfinder” are correct?

- (1) It allows the user to preview the image
- (2) It allows the light to enter the camera
- (3) It can be a hole or a lens
- (4) It is not useful at all

- A. (1) and (2)
- B. (2) and (3)
- C. (3) and (4)
- D. (1) and (3)

13) Which of the following statements about “Flip-up mirror” are correct:

- (1) It is a movable mirror
- (2) It reflects the light from the object to the viewfinder
- (3) It will be flipped down when you take a photo
- (4) It refracts the light from the object

A. (1) and (2)

B. (2) and (3)

C. (3) and (4)

D. (1) and (3)

14) Which of the following statements about “shutter” are correct:

- (1) It is a gate in front of the film
- (2) It is an opaque plastic
- (3) It reflects the light from the object to the viewfinder
- (4) It prevents light from reaching the film

A. (1) and (2)

B. (2) and (3)

C. (2) and (4)

D. (1) and (2) and (4)

15) Which of the following statement is true?

- A. Thinner convex lens refracts light to a greater extent
- B. Thicker convex lens refracts light to a lesser extent
- C. Thinner convex lens has a weaker refractive power**
- D. Thicker convex lens has a weaker refractive power

Unit 2 – The Chemistry of Image Capturing

1. Introduction

After introducing how light from the object can be directed to the film inside the camera, the chemical process of how the light reacts with the film and recorded will be explained. A photographic film consisting of different layers of materials which are necessary for it to function properly will also be introduced. Since a series of chemical reactions are involved in image capturing by film, basic chemical knowledge will be first illustrated with examples.

In Unit 2, chemical knowledge and working principles of image capturing by the film will be explained. The different materials used, their chemical structures and the chemical composition of a roll film will be introduced. The chemical reactions that happened during image capturing, such as photoreaction and redox reaction, will be illustrated with real examples. You are expected to understand the process of capturing an image by film, and this unit paves the road for understanding Unit 3 and Unit 4.

2. Summary of Unit 2

2.1 The structure of a film

- ◆ A film consists of four main parts:
 - Protective coating
 - Emulsion
 - Base
 - Anti-halation backing
- ◆ Protective coating
 - It is transparent and the top layer of the film
 - Protects the second and the third layer, emulsion and base layer, from scratches and abrasions
 - This layer will be removed during film development
- ◆ Base
 - It is the thickest layer of the film
 - Provides mechanical support to the whole film
 - Made of polyester (plastic) or aluminium foil
- ◆ Anti-halation backing
 - It is very dark in colour and the bottom layer of the film
 - Prevents the light from reflecting back up to the emulsion layer
 - Which will cause disturbance to the existing image
- ◆ Emulsion
 - It is the second layer and the “heart” of the film
 - “Stores” the light by using different chemical compounds
 - It can be categorised to: 1) colour film 2) black-and-white film
 - Chemical reactions occur in this layer when taking a photo

2.2 Camera film

Emulsion layer of the film:

- ◆ This layer consists of silver halide crystals (e.g. AgBr)
- ◆ The silver bromide (AgBr) is grey
- ◆ AgBr can react with light and becomes black
- ◆ **Silver bromide (AgBr):**
 - 1) It is an ionic salt
 - 2) It is in a face-centred cubic lattice structure
 - 3) Ag donates one electron and becomes Ag^+
 - 4) Br accepts the electron and becomes Br^-

The electron configuration of silver and bromine:

- ◆ Silver (Ag): $[\text{Kr}]4d^{10}5s^1$ or [2,8,18,18,1]
- ◆ Bromine (Br): $[\text{Ar}]3d^{10}4s^24p^5$ or [2,8,18,7]

The electron configuration of silver bromide:

- ◆ Silver ion (Ag^+): $[\text{Kr}]4d^{10}$ or [2,8,18,18]
- ◆ Bromide ion (Br^-): $[\text{Ar}]3d^{10}4s^24p^6$ or [2,8,18,8]

When the light emitted from or reflected by the target reaches the camera film:

- ◆ The AgBr salt on the film reacts with the light
- ◆ The photon kicks out one electron from the bromide, and it becomes bromine
- ◆ Silver ion receives the electron and becomes a silver atom
- ◆ The silver atoms will move together and become black
- ◆ Overall reaction: $2\text{AgBr(s)} + \text{photon (light)} \longrightarrow 2\text{Ag(s)} + \text{Br}_2\text{(g)}$
(Grey) (Black)

Oxidation and reduction (Redox reaction):

- ◆ Redox reaction is related to the movement of electron/oxygen/hydrogen between atoms or ions

	Movement of electron	Movement of oxygen	Movement of hydrogen	Oxidation number (O.N.)
Oxidation	Electron loss	Oxygen gain	Hydrogen loss	Increase
Reduction	Electron gain	Oxygen loss	Hydrogen gain	Decrease

- ◆ The reaction of AgBr on the film is an example of a redox reaction
- ◆ Where the silver ion is reduced (O.N. changed from +1 to 0) while the bromide ion is oxidised (O.N. changed from -1 to 0)

The process of image capturing:

- ◆ Once the light emitted from or reflected by the object reached the film
- ◆ It reacts with the AgBr salt on the film, and the Ag ion is reduced to form silver atoms which are black
- ◆ The black colour formed is called a latent image, which cannot be observed by naked eyes
- ◆ Since the amount of black Ag(s) is too little to form a visible image
- ◆ We need to use a series of reactions to process the latent image in order to observe it
- ◆ And this process is called photo development which will be discussed in the next unit

3. References

Charles S. and Johnson, JR., Science for the Curious Photographer, second edition, Routledge, 2010

Nichole Marie Witten, The Chemistry of Photography, University of South Carolina Scholar Commons, Spring 5-5-2016.

Photographic films, University of Houston College of Technology, Page 1-8

Photos in a Coffee Can
Unit 2 – The Chemistry of Image Capturing

Student Worksheet

1) Which of the following layers are parts of a camera film?

- (1) Protective coating
- (2) Emulsion
- (3) Base
- (4) Anti-halation backing

- A. (1) and (2)
- B. (2) and (3)
- C. (1) and (2) and (3)
- D. (1) and (2) and (3) and (4)

2) Which of the following statements about protective coating are correct?

- (1) It is the top layer of the camera film
- (2) It contains silver bromide
- (3) It is used to protect the other layers
- (4) It is opaque

- A. (1) and (2)
- B. (2) and (3)
- C. (1) and (3)
- D. (2) and (3) and (4)

3) Which of the following statements about the base layer are correct?

- (1) It is the bottom layer of the camera film
- (2) It is the thickest layer of the camera film
- (3) It is used to support the whole film
- (4) It is a piece of metal

- A. (1) and (2)
- B. (2) and (3)
- C. (1) and (3)
- D. (2) and (3) and (4)

4) Which of the following statements about the anti-halation backing are correct?

- (1) It is the middle layer of the camera film
- (2) It is dark in colour
- (3) It is used to protect the whole film
- (4) It is used to prevent the light from reflecting back

- A. (1) and (2)
- B. (2) and (3)
- C. (1) and (3)
- D. (2) and (4)

5) Which of the following statements about the emulsion layer are correct?

- (1) It contains silver bromide
- (2) It is the top layer of the film
- (3) It is used to protect the whole film
- (4) It is used to “capture” the light

- A. (1) and (2)
- B. (2) and (3)
- C. (1) and (3)
- D. (1) and (4)

6) Silver bromide (AgBr) is:

- (1) An ionic compound
- (2) An organic compound
- (3) Arranged in a face-centred cubic unit cell
- (4) A plastic

- A. (1) and (2)
- B. (1) and (3)
- C. (2) and (3)
- D. (2) and (4)

7) The electron configuration of silver atom is:

- A. $[\text{Ar}]4d^{10}5s^1$
- B. $[\text{Ar}]4d^{10}$
- C. $[\text{Kr}]4d^{10}5s^1$
- D. $[\text{Kr}]4d^{10}$

8) The electron configuration of bromine atom is:

- A. $[\text{Ar}]3d^{10}4s^24p^5$
- B. $[\text{Ar}]3d^{10}4s^24p^6$
- C. $[\text{Kr}]3d^{10}4s^24p^5$
- D. $[\text{Kr}]3d^{10}4s^24p^5$

9) The electron configuration of silver ion is:

- A. $[\text{Ar}]4d^{10}5s^1$
- B. $[\text{Ar}]4d^{10}$
- C. $[\text{Kr}]4d^{10}5s^1$
- D. $[\text{Kr}]4d^{10}$

10) The electron configuration of bromide ion is:

- A. $[\text{Ar}]3d^{10}4s^24p^5$
- B. $[\text{Ar}]3d^{10}4s^24p^6$
- C. $[\text{Kr}]3d^{10}4s^24p^5$
- D. $[\text{Kr}]3d^{10}4s^24p^5$

11) Which of the following statements about oxidation are correct?

- (1) Oxidation occurs when the charge of an atom/ion increases
- (2) Oxidation occurs when the charge of an atom/ion decreases
- (3) Oxidation occurs when the number of oxygen atom in a compound increases
- (4) Oxidation occurs when the number of hydrogen atom in a compound increases

- A. (1) and (2)
- B. (1) and (3)
- C. (2) and (3)
- D. (3) and (4)

12) Which of the following statements about reduction are correct?

- (1) Reduction occurs when the charge of an atom/ion increases
- (2) Reduction occurs when the charge of an atom/ion decreases
- (3) Reduction occurs when the number of oxygen atom in a compound increases
- (4) Reduction occurs when the number of hydrogen atom in a compound increases

- A. (1) and (2)
- B. (1) and (3)
- C. (2) and (4)
- D. (3) and (4)

13) Which of the following statements about oxidation number (O.N.) is correct?

- A. We can only find out the oxidation number of an ionic compound
- B. The oxidation number of oxygen element is 0
- C. Oxidation occurs when the oxidation number of an atom/ion decreases
- D. Reduction occurs when the oxidation number of an atom/ion increases

14) What would happen when the light reaches the camera film:

- (1) Only a small amount of AgBr salt would become Ag(s) and Br₂(g)
- (2) A visible image would be formed
- (3) A latent image would be formed
- (4) All the Ag(s) would become Ag ions

A. (1) and (2)

B. (1) and (3)

C. (2) and (3)

D. (3) and (4)

15) Which of the following reactions is a redox reaction:

A. $\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$

B. $\text{NaOH} + \text{HCl} \rightarrow \text{H}_2\text{O} + \text{NaCl}$

C. $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$

D. $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

Unit 3 – The Birth of a Photograph

1. Introduction

In Unit 1 and 2, you have been familiarised with different physical and chemical knowledge of light and image capturing. These are all essential elements for understanding the science of film development. The working mechanism and underlying principles of film development involve different chemical reactions between different chemical reagents and the film, such as redox reactions, acid-base reactions and salt dissolving. In addition, basic knowledge of photography skills will also be introduced, which can help you to create, design and develop your own photo in Unit 4.

In this unit, different chemical reagents used for film development will be introduced. In addition, the science behind the film development process will be explained based on different chemical theories in the SS syllabus.

2. Summary of Unit 3

2.1 Film development process

What is film development?

- ◆ It is a process to convert the film with a latent image which is invisible to human eyes
- ◆ To a film with a visible image
- ◆ It involves different steps and a series of chemical reactions

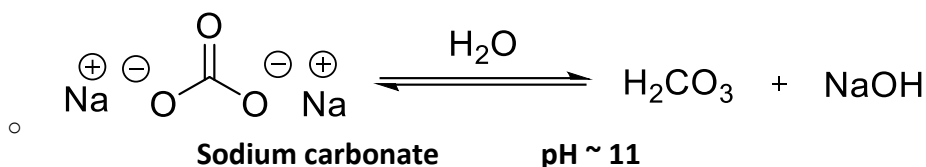
Film development process:

- ◆ Four main chemical reagents:
 - The developing agent
 - The accelerator
 - The restrainer
 - The fixer
- ◆ The developing agent:
 - It is a reducing agent
 - Used to reduce the remaining AgBr on the film to Ag(s) and Br₂(g)
 - The rate of this reduction would be much higher in the area of the latent image
- ◆ Why do we need the developing agent?
 - When we take a photo, the light from the object can only convert a very little amount of AgBr (grey) on the film to Ag(s) (black) and Br₂(g)
 - Therefore, we cannot observe the latent image formed on the film directly
 - In order to make it visible, we need to increase the number of the Ag(s) in the area of the latent image
 - So, we need to use a reducing agent (the developing agent), which can reduce the AgBr to Ag(s) in the area of the latent image

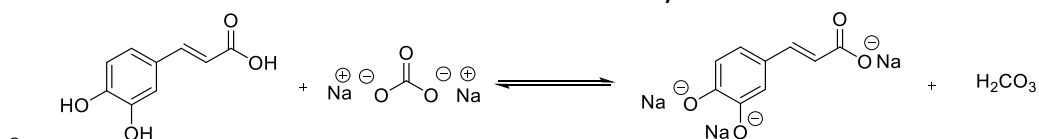
- Once the number of the Ag(s) increases, the latent image will become visible (visible image)
- ◆ The most commonly used developing agents:
 - Monomethyl-p-aminophenol sulfate
 - Hydroquinone
 - Phenidone
- ◆ These chemicals are skin and eye irritants, causing skin problems and allergies
- ◆ They are also toxic if ingested, possibly fatal for adults
- ◆ We should avoid using them
- ◆ In this module, we would use two developing agents which are safe to eat
 - Caffeic acid (found in instant coffee powder)
 - Ascorbic acid (Vitamin C)
- ◆ Both of them are used as reducing agents to reduce the AgBr on the film
- ◆ **The accelerator:**
 - It is used to increase the rate of reduction of AgBr
 - Must be used together with the developing agent
 - The accelerator can provide a basic or alkaline environment for the reduction to occur
 - It also increases the reducing power of the developing agent
 - Without the accelerator, the reduction would be too slow

Example: Sodium carbonate

- Which pH is about 11 in water
- Provides a basic environment for the reduction of AgBr to occur



- Sodium carbonate can react with caffeic acid by an acid-base reaction



- The deprotonated caffeic acid becomes more electron-rich with stronger reducing power
- Therefore, the rate of reduction of the AgBr on the film will be higher
- ◆ **The restrainer:**
 - It is used to slow down or even stop the reduction of AgBr
 - If the restrainer is not added, all the AgBr grains, no matter with or without latent image, will be reduced
 - And become black
 - Finally, the photo will become all-black without an image shown

Example: Water

- It is used to reduce the pH of the medium in order to slow down the reduction

- Since the photo developing medium should be basic (pH ~ 11), in order to reduce the concentration of $[\text{OH}^-]$
- We can increase the total volume of the solution by adding a large amount of water which pH is 7

◆ **The fixer:**

- It is used to remove the unreacted silver halide, AgBr, grains on the film
- So that the film can be exposed even though there is light
- Without degrading the image of the film

Example: Sodium thiosulfate

- AgBr does not dissolve in water
- By adding sodium thiosulfate, the AgBr can be converted to a water-soluble Ag salt which can be easily removed by water
- $$\text{AgBr} + 2\text{Na}_2\text{S}_2\text{O}_3 \longrightarrow \text{Na}_3[\text{Ag}(\text{S}_2\text{O}_3)_2] + \text{NaBr}$$

Water-insoluble
Water-soluble
Water-soluble

2.2 Converting negative image to positive image

◆ **For a black-and-white film:**

- The area receiving light from the object will turn black (Ag(s), latent image)
- The area receiving no light will remain grey (AgBr)
- And this is called the negative image

◆ **Converting negative image to positive image:**

- In order to convert the negative to the positive image
- We need to use a paper called photosensitive paper
- This paper is white/dull-white at the beginning
- When there is light striking on the photosensitive paper, the particular area will become black
- (Please refer to the PowerPoint slides of Unit 3 for a more detailed explanation)

2.3 Photography skills

Common terms used in photography:

- Aperture
- f/x
- Shutter speed
- ISO

◆ **Aperture:**

- Aperture is a hole
- The thing that controls the size of the hole (aperture) is called the iris
- The amount of light that can enter the camera is directly proportional to the area of the aperture
- The area of the aperture increases, the amount of light that can enter the camera increases

◆ **We use diameter to name the aperture with different size**

- E.g. 20 mm aperture, 28 mm aperture, 40 mm aperture
- Since the area of a hole can be calculated using the equation: $\text{area} = \pi r^2$
- and diameter (D) = $2r$
- Therefore, we can double the area of the hole by multiplying the diameter by $\sqrt{2}$
- Therefore, $20 \text{ mm} \times \sqrt{2} = 28 \text{ mm}$, $28 \text{ mm} \times \sqrt{2} = 40 \text{ mm}$ and so on...

◆ **F-stop (f/x):**

- It is used to describe the size of the aperture
- Given that a lens with a particular focal length, f, is used
- In order to adjust the light intensity entering the camera
- What size of aperture should be used

Examples:

- When stopping down (e.g. from f/1.4 to f/2), the size of the aperture decreases and the light intensity entering the camera will be reduced
- When stopping up (e.g. from f/2 to f/1.4), the size of the aperture increases and the light intensity entering the camera will be increased

◆ **Shutter speed:**

- Initially, the shutter is closed to prevent from any light reaching the film
- Once you press the button to take a photo
- The shutter will be opened for a while and then closed
- The duration for it to open is called shutter speed

Higher shutter speed:

- The shutter will only open for a shorter period
- Less light can reach the film, and the photo resulting will be dimmer

Lower shutter speed:

- The shutter will only open for a longer period of time
- More light can reach the film, and the photo resulted will be brighter

◆ **Clear and blurred photo of a moving object:**

- Higher shutter speed will give you a clear photo
- Lower shutter speed will give you a blurred photo

◆ **ISO:**

- It represents the light sensitivity of the film in film camera
or
- It represents the light sensitivity of the sensor in a digital camera

High ISO:

- It will give you a bright photo even in an environment with a very small amount of light (e.g. at night)

Low ISO:

- It will give you a bright photo only under an environment with a sufficient amount of light (e.g. in the daytime)

3. References

Charles S. and Johnson, JR., Science for the Curious Photographer, second edition, Routledge, 2010

Nichole Marie Witten, The Chemistry of Photography, University of South Carolina Scholar Commons, Spring 5-5-2016.

Photographic films, University of Houston College of Technology, Page 1-8

Photos in a Coffee Can
Unit 3 – The Birth of a Photograph

Student Worksheet

1) What is film development:

- A. A process to take a photo
- B. A process to obtain a latent image
- C. A process to convert a film with a visible image to a photo
- D. A process to convert a film with a latent image to the film with a visible image

2) Which of the following reagents will be used in film development?

- (1) The accelerator
- (2) The cleaner
- (3) The restrainer
- (4) The oxidising agent

- A. (1) and (2)
- B. (2) and (3)
- C. (1) and (3)
- D. (2) and (3) and (4)

3) What is the developing agent?

- A. A base
- B. An oxidising agent
- C. A reducing agent
- D. None of the above

4) Which of the following statements is true about the developing agent?

- A. It is used to oxidise AgBr salt on the film
- B. It is used to remove AgBr salt on the film
- C. It is used to reduce AgBr salt ion the film
- D. It is used to increase the pH of the developing medium

5) Which of the following agents can be used as the developing agent?

- (1) Hydroquinone
 - (2) Caffeic acid
 - (3) Vitamin C
 - (4) Acetone
-
- A. (1) and (2)
 - B. (2) and (3)
 - C. (1) and (3)
 - D. (1) and (2) and (3)

6) What is the function of the accelerator?

- A. To remove AgBr
- B. To increase the pH of the developing medium
- C. To increase the rate of reduction of AgBr on the film
- D. To reduce the rate of reduction of AgBr on the film

7) Which of the following statements is/are true about the accelerator?

- (1) It provides a basic environment for the reduction to occur
- (2) It provides an acidic environment for the reduction to occur
- (3) It is used to stop the reduction of AgBr on the film

- A. (1)
- B. (1) and (2)
- C. (2) and (3)
- D. (1) and (2) and (3)

8) What is the function of the restrainer?

- A. To slow down or stop the reduction of AgBr on the film
- B. To increase the rate of reduction of AgBr on the film
- C. To provide an acidic medium for the reduction to occur
- D. To remove the AgBr on the film

9) Why can water be used as the restrainer?

- A. Its pH value is 7
- B. It provides an acidic medium
- C. It provides a basic medium
- D. It can dissolve AgBr

10) What is the function of the fixer?

- A. To reduce AgBr on the film
- B. To provide an acidic environment for the reduction to occur
- C. To remove the unreacted silver halide grains on the film
- D. To stop the reduction of AgBr

11) How does the fixer work?

- A. To convert AgBr to other Ag salts which is insoluble in water
- B. To convert AgBr to other Ag salts which is soluble in water
- C. To remove AgBr
- D. None of the above

12) Which of the following reagents can be used as the fixer?

- (1) Sodium thiosulfate
- (2) Ammonia
- (3) Acetone
- (4) Water

- A. (1) and (2)
- B. (2) and (3)
- C. (2) and (4)
- D. (1) and (2) and (4)

13) Which of the following statements about aperture are correct?

- (1) When the diameter of the aperture increases, the area of it will increase
- (2) When the diameter of the aperture increases, the area of it will decrease
- (3) When the area of aperture increases, more light can approach the film
- (4) When the area of aperture increases, less light can approach the film

- A. (1) and (3)
- B. (2) and (3)
- C. (2) and (4)
- D. (1) and (2) and (4)

14) Which of the following statements about shutter speed are correct?

- (1) Higher the shutter speed, brighter the photo
- (2) Lower the shutter speed, brighter the photo
- (3) Higher the shutter speed, more clear the photo of a moving object
- (4) Lower the shutter speed, more clear the photo of a moving object

- A. (1) and (2)
- B. (2) and (3)**
- C. (1) and (3)
- D. (2) and (4)

15) Which of the following statements about ISO are correct?

- (1) Represents the light sensitivity
- (2) Higher the ISO, higher the light sensitivity
- (3) Higher the ISO, lower the light sensitivity
- (4) Higher the ISO, stronger the noise of the photo

- A. (1) and (2)
- B. (2) and (3)
- C. (1) and (3)
- D. (1) and (2) and (4)**

Unit 4 – I Am a Film Developer

1. Introduction

In order to have a comprehensive understanding of the science of photography, including light, image capturing, and film development, you are provided with a chance to experience all three processes in this unit. In addition, you have been equipped with scientific knowledge introduced in Units 1, 2 and 3 and should be able to handle and master them.

In Unit 4, you can take a photo using a film camera or a 3D DIY pinhole camera. You will then develop your own film using instant coffee powder and vitamin C. The chemical properties and reactions during film development of coffee powder and vitamin C will be introduced. Finally, the developed film will be scanned, and the resulting photo with good quality will be given to you, and you will be encouraged to share your ideas and think about your own artwork.

2. Summary of Unit 4

Film development

- ◆ To first take a photo by using a film camera
- ◆ To develop the film by using instant coffee powder and vitamin C
- ◆ To scan the developed film by using a film scanner

3. Duration

Two hours for each experiment

4. Objective

To consolidate the techniques and chemistry knowledge of film development

5. Equipment and materials

Equipment

1. 35 mm black and white film (suggested: **Ilford** Delta 400; HP5 Plus; **Kodak** TMAX 400; **Fomapan** 400)
2. 135 point and shoot film camera / 135 3D print pinhole camera
3. Film scanner
4. Development tank
5. Changing bag
6. Scissors
7. Rubber dust blower

8. Hanger and clip
9. Glass rod/stir bar
10. 2L measuring jugs/beakers

Materials

1. Instant coffee powder (containing caffeic acid)
2. Vitamin C (powder form)
3. Washing soda (sodium carbonate)
4. Potassium bromide
5. Fixer

Procedures

1. Take photos:
 - i. Load the film into the camera. Each roll of film can take 36 photos. Make sure the settings on your camera are correct, especially ISO value.
 - ii. Have fun taking photos.
 - iii. Retrieve the film after taking all the photos. The camera may do it for you.
2. Preparation of **coffee-developer**:
 - i. Weigh 27 g of washing soda, 8 g of vitamin C, 0.5 g of potassium bromide, 20 g of instant coffee into a 500 ml measuring jug.
 - ii. Pour ~500 ml of deionised water into the jug. Mix using a glass rod until all the chemicals/ingredients are completely dissolved. Rest for 5 minutes.
3. Preparation of **diluted-fixer**:
 - i. Dilute 50 mL of fixer into 500 mL deionized water.
4. While you are waiting, load the film into the development tank by following this video (2'09" onwards): https://www.youtube.com/watch?v=efgJqUkD_VI.
MAKE SURE THE ENTIRE PROCESS IS DONE IN THE CHANGING BAG UNTIL YOU CLOSE THE TANK LID.
5. After loading the film in the development tank, close the lid tightly and take it out from the changing bag.
6. Pour the **coffee-developer** into the development tank and agitate for 10 seconds each minute for 8 minutes.
7. Pour out all the liquid from the development tank. Pour water into the tank and agitate the tank. This step removes the remaining developer in the tank. Repeat this step three times.
8. Add fixer and agitate for 10 seconds each minute for 6 minutes.
9. Repeat **Step 7**.
10. Remove the film from the tank. Clip and hang dry.
11. Scan and digitise your photos.

Result and Discussion:

- ◆ Worksheet related to the film development for each student
- ◆ Performance evaluation

6. References

Charles S. and Johnson, JR., Science for the Curious Photographer, second edition, Routledge, 2010

Nichole Marie Witten, The Chemistry of Photography, University of South Carolina Scholar Commons, Spring 5-5-2016.

Photographic films, University of Houston College of Technology, Page 1-8

Photos in a Coffee Can
Unit 4 – I Am a Film Developer

Student Worksheet

Film development

1. Why do we need to load the film on the wheel inside the changing bag?

2. What is the main function of using instant coffee powder and vitamin C?

3. What is the main function of using the fixer?

Paste the developed film and the black-and-white photo:

The developed film:

The black-and-white photo:

4. Why is the colour of the images on the film and on the photo not the same?
