International Advance Journal of Engineering, Science and Management (IAJESM)
Multidisciplinary, Indexed, Double Blind, Open Access, Peer-Reviewed, Refereed-International Journal.
SJIF Impact Factor =7.938, July-December 2024, Submitted in October 2024, ISSN -2393-8048

Significance of Chlorophenol Red in Liquid Phase Dye Sensitized Photogalvanic Cell for Solar Power Generation by Utilizing Ascorbic Acid and Tween 80 Chemicals

Parveen Kumar, Ph.D Research Scholar, Department of Chemistry, Shri Jagdishprasad Jhabarmal Tibrewala University, Jhunjhunu, Rajasthan
Dr. Vishnu Dev Gupta, Department of Chemistry, Shri Jagdishprasad Jhabarmal Tibrewala University, Jhunjhunu, Rajasthan
Dr. Kewal Singh, Department of Chemistry, S.G.N. Khalsa P.G. College, Sri Ganganagar, Rajasthan, India

Abstract

Solar energy is energy derived from the **sun's radiation**. It's one of the cleanest, most abundant and renewable sources of energy available. Photo electrochemical cells are another method for generating electricity. Although they aren't cost-effective for large-scale power production, but they may be quite helpful for producing energy in applications like satellites and traffic lights in outlying places, where other options aren't viable. Therefore, solar electricity has practical but limited uses, which will undoubtedly expand as the price of photo electrochemical cells decreases. The photogalvanic cells as described in the present research work are energy devices as they provide for a route for simultaneous solar energy conversion and its storage. The photogalvanic effect of Chlorophenol red- ascorbic acid-tween-80 system has been studied in alkaline medium at low intense light with aim of searching relatively proper combination of chemicals like photosensitizer, reductant and surfactant for further enhancing the efficiency of photogalvanic cell.

Keywords: Chlorophenol red, ascorbic acid, tween-80, Photogalvanic effect, fill factor, power point, and conversion efficiency.

1. Introduction

Energy is very important for a country's growth. However, relying too much on traditional energy sources leads to more pollution, like carbon dioxide, which makes global warming worse and harms nature. Because of this, the environmental issue and the energy problem are connected. The world's need for energy is growing because there are more people and they want a better quality of life.[1]

Energy that is produced by natural processes and constantly replenished is known as renewable energy. Solar energy is universal, decentralized, non-polluting, freely available energy source and essential for every kind of living organism. Photogalvanic cell an important device that provides desirable route for conversion of solar energy into electrical energy. It is a third type of photoelectrochemical cell which is used for solar energy conversion.[2] In photogalvanic cell two inert electrodes are used and the light is absorbed by the electrolytic dye solution. An electron transfer occurs between the excited photo sensitizer dye molecules and electron donor or acceptor molecules added to the electrolyte. A photovoltage between the two electrodes is developed if the light is absorbed by the electrolytic solution. Accordingly, the photogalvanic cell is essentially a concentration cell and is based on some photochemical reaction, which gives rise to high energy products on excitation by a photon. This energy product loose energy electrochemically lead to generate the electricity called as a photogalvanic effect. First of all this effect was observed in equilibrium of ferrous ferric iodine iodide but this effect was systematically investigated in Thionine-Fe system.[3-6] Thionine has been condensed with poly (N-methylolacrylamide) to give a polymer-dye complex. Depending on the polymer-dye ratio, a longer wavelength shift (red shift) is observed as compared to the spectrum of free thionine. Potential of photogalvanic is found to depend strongly on the polymer-dye ratio.[7] The photo potential and current in photogalvanic cell containing toluidine blue and reductant, Fe (II), EDTA, triethanolamine and triethylamine have been determined. The power output with EDTA or amines as reductant were higher than Fe (II). The efficiency of the EDTA-Toluidine blue photogalvanic cell has been estimated to be about 0.0022%. The photoelectrochemical behaviour of toluidine blue in the presence of reductant has been examined by cyclic voltametry.[8] Photogalvanic cells may play an important role in direct conversion of solar energy to electrical energy by some photochemical reactions. A number of photogalvanic systems have been fabricated with the aim of obtaining higher power output. A few among the studied photogalvanic systems with their maximum photopotential are: thionine-Fe ion aqueous system 250 mV, proflavine-EDTA aqueous system 476 mV and tolusafranine-EDTA aqueous system 844 mV. Authors have reported a photopotential 615 mV in a redox system consisting of phenosafranine and EDTA in aqueous medium and this value increases with increasing temperature attaining 870 mV.[9] Photogalvanic cells using toluidine blue-diethylenetriamine penta acetic acid and methylene blue-EDTA have been developed. Current-voltage characteristics and performance of the cell were determined.[10-11] Gangotri et al have increased the electrical output as well as storage capacity up to reasonable mark by using various photosensitizer with micelles in photogalvanic cell.[12-13] Photogalvanic effect was studied in a photogalvanic cell containing ammonium lauryl sulphate, ascorbic acid and Azur-A as a surfactant, reductant and photosensitizer, respectively. The effects of different parameters on the electrical output of the cell were observed. The observed conversion efficiency and storage capacity for this system were 0.5461 % and 110 minutes, respectively.[14] Genwa and Singh[15-17] have reported reasonable values of electrical output with different dyes i.e. Brilliant Blue, lissamine green-B and bromocresol green as photosensitizers in Photogalvanic cells for solar power generation and storage. The photogalvanic effect of Xylidine ponceau dye was studied in Xylidine ponceau–tween 60–ascorbic acid system. Conversion efficiency was calculated by photo potential and current values at power point.[18] Modified photogalvanic cell for increasing the power and storage capacity have studied in EDTA- Safranine O system. This cell showed greatly enhanced performance in terms of charging time forty minutes, equilibrium photocurrent 1700 μA, power 364.7 μW and conversion efficiency (8.93%).[19] The photogalvanic effect observed by Gangotri and Mohan[20-21] in Trypan blue- arabinose and nile blue- arabinose photogalvanic cell systems cells. Photogalvanic effect also observed in spinach extract as photo-sensitizer for solar energy conversion and storage. The observed cell performance (charging time 18 minutes, V_{oc} 1050 mV, I_{sc} 1750 μA, storage capacity as half change time 44 minutes and conversion efficiency ≈ 9.22%) was very encouraging to photogalvanics.[22] An investigation on the photogalvanic effect was carried out by Rathore and Singh[23] using a Janus green B-DSS-EDTA system. As a reductant, EDTA is employed in this process, while the azo dye Janus green B is used as photo sensitizers. At its power point, the system is capable of producing power equal to 164.1 µW. The fill factor for the system is 0.33, while the system's conversion efficiency is 1.58%. In the dark, the cell operates for 180 minutes. The scientific society has used different photosensitizers, surfactants, reductants in photogalvanic cells for conversion of solar energy into electrical energy but no attention has been paid to the use of this system containing chlorophenol red, ascorbic acid and tween-80 chemicals as energy material to enhance the power output and performance of the photogalvanic cell. Therefore, the present work was undertaken to obtain better performance and commercial viability of the photogalvanic cell.

2. Result and discussion

(a) Effect of variation of Chlorophenol red, ascorbic acid and tween 80 concentration:

The impact of variation of chlorophenol red, ascorbic acid and tween80 concentration are given in table 1. The changes in dye concentration were also studied by using solution of chlorophenol red at different concentrations. It was observed that the photopotential, photocurrent and power increased with increasing in concentration of the chlorophenol red. Maximum values of electrical output were obtained for a particular value of chlorophenol red concentration (2.6 x 10^{-5}M), above which a decrease in electrical output of the photogalvanic cell was observed. Low electrical output observed at the minimum concentration range of dye due to limited number of chlorophenol red molecules to absorb the major part of the light in the path, while higher concentration of chlorophenol red again resulted in a decrease in electrical output because intensity of light reaching to those dye molecules which are near to the electrode decreases due to absorption of the major portion of the light by the chlorophenol red molecules present in the path. Therefore corresponding fall in the

International Advance Journal of Engineering, Science and Management (IAJESM)
Multidisciplinary, Indexed, Double Blind, Open Access, Peer-Reviewed, Refereed-International Journal.
SJIF Impact Factor =7.938, July-December 2024, Submitted in October 2024, ISSN -2393-8048

electrical output. With increasing the concentration of the ascorbic acid, photopotential, current and power were found to increase till it reaches a maximum value at 1.9 x 10^{-3} M. These values are 850.0 mV, 836.0 µA and 710.60 µW respectively. On further increase in concentration of ascorbic acid, a decrease in the electrical output of the cell was observed. The fall in power output was also resulted with decrease in concentration of ascorbic acid due to less number of molecules available for electron donation to the chlorophenol red dye. On the other hand, the movement of dye molecules hindered by the higher concentration of the ascorbic acid to reach the electrode in the desirable time limit and it will also result into a decrease in electrical output. The electrical output of the cell was increased on increasing the concentration of tween 80. Optimum result was obtained at a certain value (2.8 x 10^{-3} M) of concentration of tween 80. On further increasing the surfactant concentration it react as a barrier and major portion of the surfactant photobleach the less number of dye molecules so that a down fall in electrical output was observed.

Table -1. Effect of variation of Chlorophenol red, ascorbic acid and tween 80 concentrations

Light Intensity = 10.4 mW cm^{-2} , Temperature = 303 K , pH = 12.28

Concentrations	Photopotential (mV)	Photocurrent (µA)	Power (µW)
[Chlorophenol red]×10^{-5} M			
2.1	658.0	609.0	400.72
2.4	761.0	724.0	550.96
2.6	850.0	836.0	710.60
2.8	759.0	687.0	521.43
2.9	647.0	577.0	373.31
[Ascorbic acid] x 10^{-3} M			
1.5	675.0	543.0	366.53
1.7	777.0	664.0	515.93
1.9	850.0	836.0	710.60
2.1	781.0	659.0	514.68
2.4	682.0	579.0	394.88
[Tween 80] x 10^{-3} M			
2.4	657.0	641.0	421.14
2.7	810.0	783.0	634.23
2.8	850.0	836.0	710.60
3.0	783.0	764.0	598.21
3.2	634.0	647.0	410.20

(b) Effect of variation of pH

PG cell containing chlorophenol red – ascorbic acid –Tween 80 system was found to be quite sensitive to pH of the solution. It was studied that there is an increase in the electrical output of the system on increases the pH. At pH 12.28 a maxima was obtained in photo potential, current and power (850.0 mV, 836.0 µA and 710.60 µW). On further pH increases, there was a decrease in electrical output. The optimum electrical output was obtained at particular pH value; it may be due to better availability of ascorbic acid in donar form at that pH value. The results showing the impact of pH are represented in the table 2.

Table –2 Effect of Variation of pH

pH	Photopotential (mV)	Photocurrent (µA)	Power (µW)
12.10	654.0	633.0	413.98
12.18	744.0	712.0	529.73
12.28	850.0	836.0	710.60
12.37	768.0	700.0	537.60
12.48	682.0	607.0	413.97

(c) Impact of diffusion length

The impact of variation of diffusion length (it is distance between the two electrodes) on the current parameters of the cell (i_{max}, i_{eq} and initial rate of generation of photocurrent) was studied using H-shaped glass cells of different dimensions. It was observed that in the first few minutes of illuminations there is sharp increase in the photocurrent. As consequences, the maximum photocurrent (i_{max}) increase in diffusion length because path for photochemical reaction was increased, but this is not observed experimently whereas equilibrium photocurrent (i_{eq}) decreased linearly. Therefore, it may be concluded that the main electroactive species are the leuco or semi form of dye (photosensitizer) in the illuminated and dark chamber respectively. The ascorbic acid and its oxidation product act only as electron carriers in the path. The results are given in table 3.

Table- 3 Effect of Diffusion Length

Diffusion Length DL (mm)	Maximum Photocurrent i_{max} (μA)	Equilibrium Photocurrent i_{eq} (μA)	Rate of initial Generation of Current (μA min^{-1})
40.00	854.0	840.0	22.47
45.00	856.0	838.0	22.53
50.00	858.0	836.0	22.58
55.00	860.0	834.0	22.63
60.00	862.0	832.0	22.68

(c) Impact of light intensity

The effect of light intensity was studied by using intensity meter (Solarimeter model-501). It was found that photocurrent showed a linear increasing behaviour with the increase in light intensity whereas photo potential increases in a logarithmic manner. The impact of change in light intensity on the photo potential and current is graphically represented in figure 1.

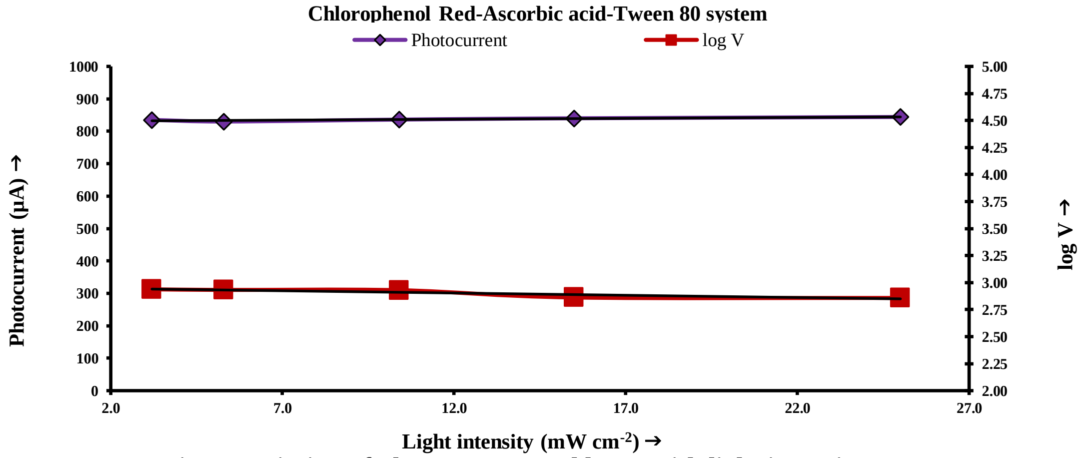


Fig. 1 Variation of photocurrent and log V with light intensity

(d) Current-Voltage (i-V) properties of the cell

The short circuit current (i_{sc}) 836 μA and open circuit voltage (V_{oc}) 850 mV of the photogalvanic cell were measured with the help of a microammeter (keeping the circuit closed) and with a digital pH meter (keeping the circuit open), respectively. The photo current and potential values in between these two extreme values were recorded with the help of a carbon pot (log 470 K) connected in the circuit of multimeter, through which an external load was applied. The i-V properties of the photogalvanic cell containing chlorophenol red, ascorbic acid and tween-80 chemicals is graphically shown in figure 2 and summarized in table 4. It was observed that i-V curve deviated from its regular rectangular shape. A point in the i-V curve, called power at point (pp), was determined where the product of photo current (i_{pp}) 495 μA and potential (v_{pp}) 250 mV was maximum. With the help of i-V curve, the fill-factor was reported 0.1427 by using the formula:

$$\text{Fill factor}(\eta) = \frac{V_{pp} \times i_{pp}}{V_{oc} \times i_{sc}}$$

International Advance Journal of Engineering, Science and Management (IAJESM)
Multidisciplinary, Indexed, Double Blind, Open Access, Peer-Reviewed, Refereed-International Journal.
SJIF Impact Factor =7.938, July-December 2024, Submitted in October 2024, ISSN -2393-8048

Table-4 Current-Voltage (i-V) characteristics of the cell

S No.	Potential (mV)	Photocurrent (µA)	S No.	Potential (mV)	Photocurrent (µA)
1.	1037	0	21.	589	200
2.	998	10	22.	576	210
3.	987	20	23.	549	220
4.	959	30	24.	529	230
5.	945	40	25.	515	240
6.	925	50	26.	495	250
7.	899	60	27.	462	260
8.	878	70	28.	435	270
9.	849	80	29.	413	280
10.	828	90	30.	400	290
11.	804	100	31.	369	300
12.	778	110	32.	344	310
13.	755	120	33.	318	320
14.	737	130	34.	294	330
15.	710	140	35.	275	340
16.	691	150	36.	256	350
17.	665	160	37.	239	360
18.	642	170	38.	221	370
19.	624	180	39.	193	390
20.	611	190			
Power (µW)				123.75 µW	
Fill Factor (η)				0.1427	

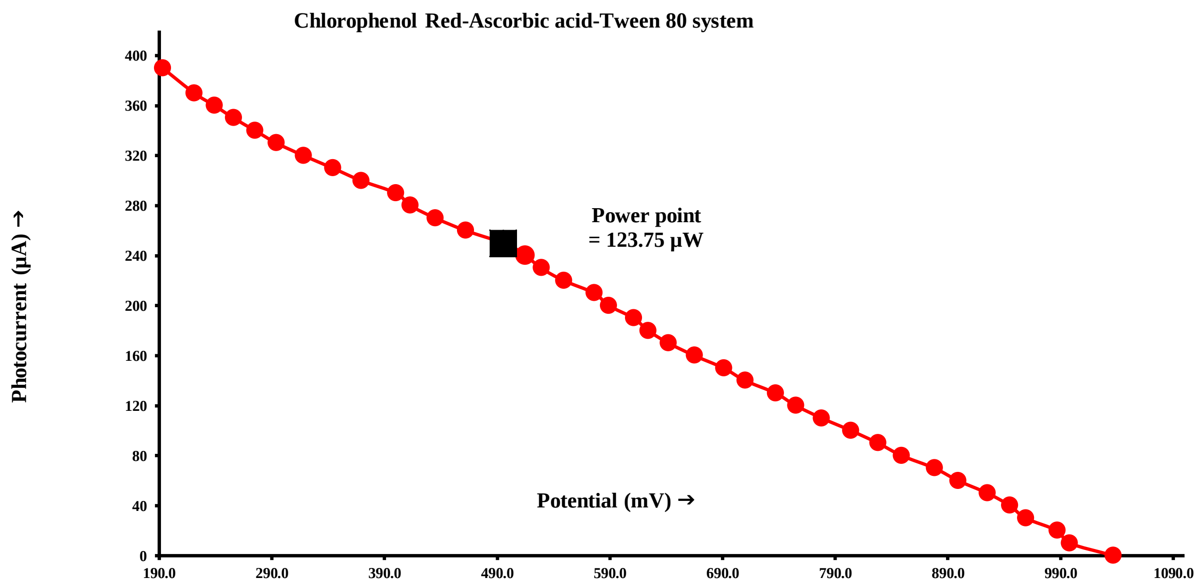


Fig. 2 current voltage properties (i-V) of the photogalvanic cell

(e) Cell performance and conversion efficiency

The performance of the photogalvanic cell was observed by applying an external load (necessary to have current at power point) after terminating the light source as soon as the potential reaches at a constant value. The performance was determined in terms of $t_{1/2}$, i.e., the time required in fall of the power output to its half at power point in dark. It was observed that the cell containing chlorophenol red- ascorbic acid-tween-80 can be used in dark for two hours. With the help of photo current and potential values at power point and the incident power of radiations, the conversion efficiency of the cell was determined as 1.1899 % using the formula. The results are graphically represented in time-power curve (figure 3).

$$\text{Conversion efficiency} = \frac{V_{pp} \times i_{pp}}{A \times 10.4 mWcm^{-2}} \times 100\%$$

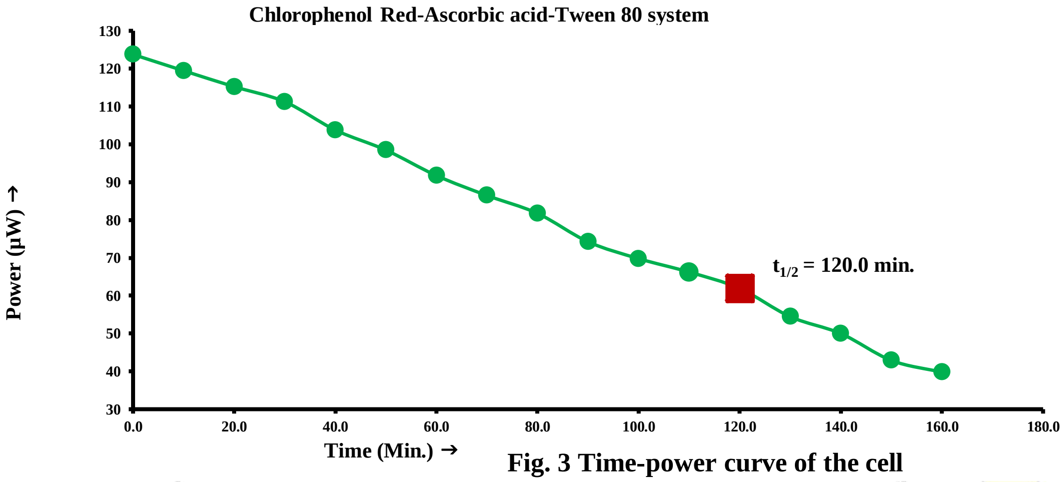


Fig. 3 Time-power curve of the cell

3. Mechanism

When the dye molecule is excited by the light in the presence of electron donating substance (ascorbic acid), the dye rapidly changed into colorless form. The dye now acts as a powerful reducing agent and can donate electron to other substance and reconverted to its oxidized state. On the basis of earlier studies a tentative mechanism in photogalvanic cell shown in figure 4.

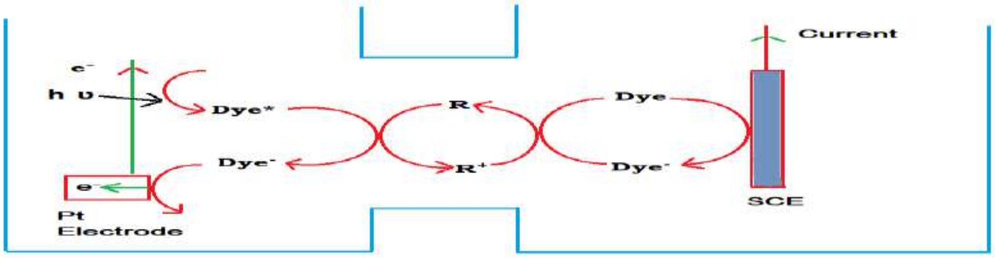


Fig. 4 Scheme of mechanism

SCE = Saturated calomel electrode D = Dye (Photosensitizer)
R = Reductant D = Semi & Leuco form

4. Objective and Methodology

How efficient is a Photogalvanic solar cell at converting the sun's energy into electrical energy? How much power does a photogalvanic cell produce? The objective of this experiment is to explore photogalvanic solar cells as renewable energy sources and test their efficiency in converting solar radiation to electrical power.

Chlorophenol red, ascorbic acid, tween-80 and NaOH of Loba Chemie were used in the present work. Stock solution of ascorbic acid, Chlorophenol red, tween-80 and NaOH (1N) were prepared in double distilled water (conductivity 3.5×10^{-5} Sm^{-1}) and kept in dark coloured containers to protect them from sun light. 25 ml volume of stock solution of chlorophenol red, ascorbic acid, tween-80 and NaOH was taken in an H–type glass tube which was blackened by black carbon paper to protect from sun light. A shiny Pt foil electrode (1.0 x 1.0 cm^2) was immersed in one limb of the H–tube and a saturated calomel electrode (SCE) was immersed in the other limb. Pt-electrode acts as a working electrode and SCE as a counter electrode. The whole system was first placed in the dark till a stable potential was attained, then the limb containing the Pt-electrode was exposed to artificial light (tungsten lamp). A water filter was used to cut off thermal radiation. A digital multimeter (HAOYUE DT830D Digital multimeter) was used to measure the photo potential and current generated by the system respectively. The i-V characteristics were studied by applying an external load with the help of Carbon pot (log 470 K) connected in the circuit the PG cell set-up is shown in figure 5.

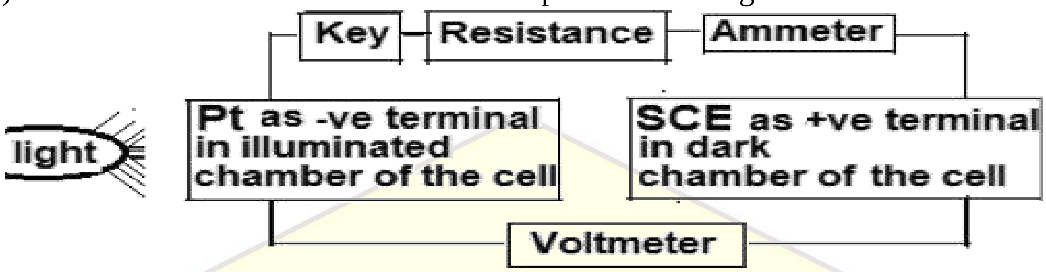
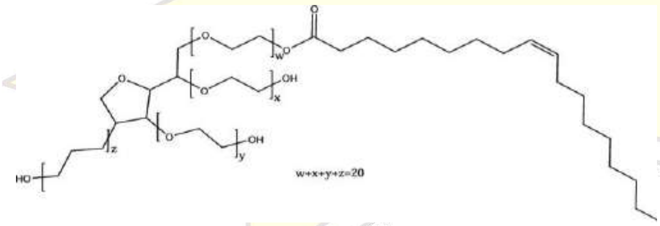
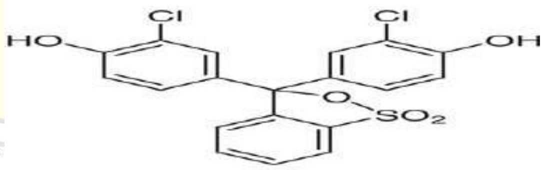


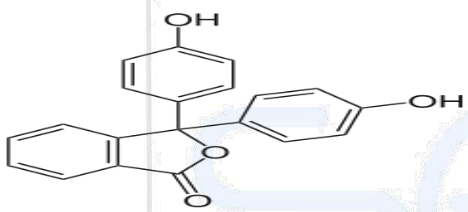
Fig.5 Photogalvanic Cell Set-up



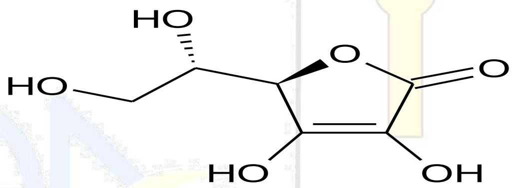
Tween-80



Chlorophenol red



Phenolphthalein



Ascorbic acid

Scheme1. Structures of chemicals

5. Conclusions

The photogalvanic cell have inbuilt storage capacity and stored energy can be used in absence of light whereas photovoltaic cell needs extra hardware as battery for energy storage, photogalvanic cells are favourable than photovoltaic cells because low cost materials are used in this system. The conversion efficiency, storage capacity, power at power point and fill factor are recorded as 1.1899 %, 120 minutes, 123.75 µW and 0.1427 respectively in Chlorophenol red-ascorbic acid – tween-80 system.

Acknowledgement

The Authors are thankful to Head, Department of Chemistry for providing necessary facilities.

References

1. Hodgson P.E., The Energy Crisis, Corpus Christi College Oxford, **140, (2008)**
2. Bard A. J, Memming R. and Miller B., Terminology in semiconductor electrochemistry and photoelectrochemical energy conversion, Pure and Appl. Chem., **63,** 569 **(1991)**
3. Kamat P.V., Karkhanawala M.D. and Moorthy P.N., Study of Ferrous- Thionine System Part II- Power Output in Homogeneous & Heterogeneous Type Photogalvanic Cells, Indian J. Chem.,**18A**, 210 **(1979)**
4. Rabinowitch E., The Photogalvanic Effect I: The Photochemical Properties of the Thionine-Iron System, J. Chem. Phys., **8**, 551 **(1940)**

5. Rabinowitch E., The Photogalvanic Effect II: The Photogalvanic Properties of Thionine-Iron System, J. Chem. Phys., **8**, 560 **(1940)**
6. Rideal E.K. and Williams E.G., The Action of Light on the Ferrous Iodine Iodide Equilibrium, J. Chem. Soc. Trans., **127,** 258 **(1925)**
7. Tamilarasan R. and Natrajan P., Photogalvanic Cell: Iron (II) - Poly (N–acrylamidomethyl thionine) System, Indian J. Chem., **20A**, 213 **(1981)**
8. Murthy A.S.N. and Reddy K.S., Studies on photogalvanic effect in system containing Toluidine blue, Solar Energy, **30**, 39 **(1983)**
9. Rohatgi-Mukherji K.K., Roy M. and Bhowmik B.B., Photovoltage Generation of the Phenosafranine Dye-EDTA Sandwich Cell, Solar Energy, **31**, 417 **(1983)**
10. Ameta S. C., Ameta R.C., Bala M and Dubey T.D., Use of toluidine blue – diethylenetriamine penta acetic acid (TB - DTPA) system in photogalvanic cell for solar energy conversion**,** J. Chim. Phys., **88,** 191 **(1991)**
11. Ameta S. C. , Khamesra S. , Chittora A. K. and Gangotri K. M., Use of sodium lauryl sulphate in a photogalvanic cell for solar energy conversion and storage: Methylene blue-EDTA system, International journal of energy research,**13**, 643 **(1989)**
12. Gangotri K.M., Genwa K. R., Kalla P., Regar O.P., Lal C. and Meena R., Photogalvanic Cells as a Device for Solar Energy Conversion and Storage, Asian J. Chem. Reviews., **5,** 69 **(1994)**
13. Gangotri K.M., Regar O.P., Lal C., Kalla P. and Meena R., Use of micelles in photogalvanic cell for solar energy conversion and storage: Toludine blue-glucose-Acetyl pyridinium chloride system, The Arabian J. Sci. Engg., **22,** 115 **(1997)**
14. Genwa K.R.and Chouhan A., Role of heterocyclic dye (Azur A) as a photosensitizer in photogalvanic cell for solar energy conversion and storage: ALS-ascorbic acid system, Solar Energy,**80,** 1213 **(2006)**
15. Genwa K.R. and Singh K., Development of photogalvanic cell and its application in solar energy conversion and storage Int. J. Chem., **1,** 542 **(2012)**
16. Genwa K. R. and Singh K., Optimum efficiency of Photogalvanic cell for solar energy conversion: Lissamine green B-ascorbic acid-ALS System, Smart Grid and Renewable Energy, **4,** 306 **(2013)**
17. Genwa K. R. and Singh K., Use of Bromocresol green- ascorbic acid-ALS System in photogalvanic cell for solar energy conversion and storage, J. Indian Chem. Soc., **90,** 813 **(2013)**
18. Genwa K. R. and Sagar C. P., Xylidine ponceau dye based photogalvanic cell: Energy conversion for sustainable development. Eur. Chem. Bull. **3,** 76 **(2014)**
19. Gangotri K. M. and Mohan, "Use of Trypan blue-Arabinose System in Photogalvanic Cell for Solar Energy Conversion and Storage." Int. J. Eng. Sci. and Res. Tech**. 3,** 6, 447-454 **(2014)**
20. Mohan and Gangotri K. M., "The optimum conversion efficiency in nile blue arabinose system by photogalvanic cell." Advances in Energy Research. **3**, 3, 143-155 **(2015).**
21. Gangotri P. and Koli P., Study of the enhancement on photogalvanics: solar energy conversion and storage in EDTA-safranine –O-ALS system. Sustainable Energy Fuels, **1,** 882 **(2017)**
22. Koli P., Photogalvanic effect of natural photosensitizer (crude Spinach extract) in artificial light for simultaneous solar power generation and storage. Environ. Prog. Sustainable Energy, **37,** 1800 **(2018)**
23. J. Rathore and K. Singh. "Use of Janus green B as photosensitiozer in EDTA-DSS system for photogalvanic conversion and storage of solar energy." Vidyabharati International Interdisciplinary Research Journal (Special Issue), International Conference on Emotions and Multidisciplinary Approaches-ICEMA 2021, **(2021)** 546. ISSN 2319-4979.