Chemical Education in Sri Lanka – A Critical View

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1. Importance of Chemistry

The Nobel prizes are awarded for three scientific disciplines namely, **Physics, Chemistry and Medicine**. The international scientific community has recognized that these three scientific disciplines would be responsible for the advancement of technological areas such as, Engineering – the application of the concepts associated mainly in physics, biology – the application of chemistry and physics. There is no limit to the research in the above three scientific disciplines. Mathematics and Computer Science can be considered as tools which are essential for the advancement of physics, chemistry and medicine.

The Watson and Crick paper entitled "A Structure for Deoxyribose Nucleic Acid (DNA)" written on the 2nd of April, 1953 was published in "Nature". In 1962 Watson, Crick and Wilkins received the Nobel Prize in Physiology or Medicine. The people responsible for the discovery of the double-helical structure of DNA were Francis Crick, Rosalind Franklin, Linus Pauling, James Watson and Maurice Wilkins. It could be said that one important aspect of biology, the DNA, was discovered by physicists and chemists. The background knowledge in physics assisted them to work out the double helical structure of DNA. A physicist and a chemist (Otto Hahn and Fritz Strassmann) in 1938 discovered the fission of nuclei of ^{235}U leading to the liberation of an enormous amount of energy which is now said to be the nuclear energy. It is obvious that chemistry played and also continues to play a vital role in the major discoveries of science. Ultimately, it is the Education in Chemistry which makes the base for the development of most of the other scientific disciplines.

Any form of economic development of a country can ultimately be traced to the development of science, but it is difficult to convince any one that science is the 'seed' of economy since 'technology' plays the obvious role in economic development. Technology can be considered as the output of scientific theories giving the final product needed for economic growth. Any form of technology cannot survive without science. Technology may flourish for sometimes but ultimately dies off if it is not supported by the scientific 'seeds'. The survival of a particular technology is dependent on its associated sciences. One could argue that ancient Sri Lanka had only the technology, which helped in booming of the economy from time to time with the assistance of good governance. It is clear that the ancient technology was based on some form of unwritten science surely *not the modern science.* Due to historical reasons most of the ancient unwritten sciences died leaving us to apply the 'modern science' to ancient as well as modern technology. Therefore, the application of modern science to technology is essential since the sustainable development of a country is based on the improvement of the technologies.

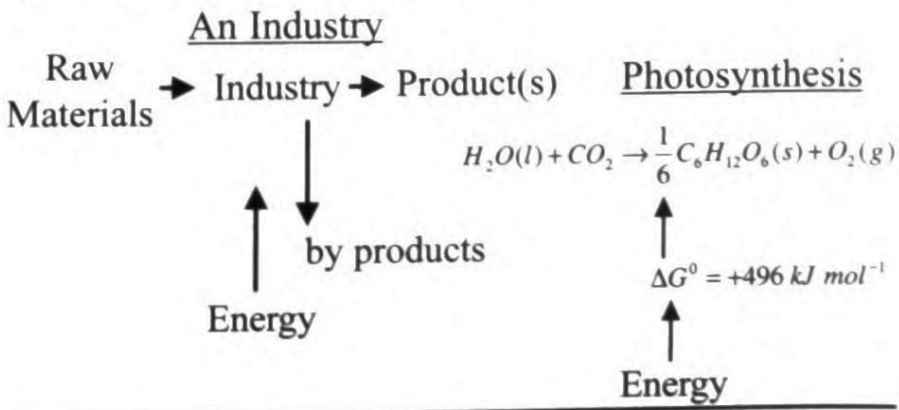
Science → Technology → To fulfill the technological needs of a country

The application of science to technology becomes fruitful if there is a scientific culture in a country where Education in Science and Technology plays a vital role. The supplication of chemical sciences to the technologies plays a vital role in the sustainability of the technologies and thus the economy of the country.

2. Teaching of Chemistry

A teacher is a person who transfers the knowledge (skill) to the student. It is the duty of the student to develop the ability to use the knowledge when the need arises. In the traditional method, scientific principles are taught applying mainly to imaginary examples. The skill is developed by carrying out the laboratory work. It is essential to develop the ability to apply the scientific principles to technologies in Sri Lanka. There is a dearth of personnel who possess this ability. (less than 10 % - "*scientific literacy*"). In the modern concept, a teacher is a facilitator who will guide the student to develop the so called "scientific literacy". The teacher will facilitate the students to develop their skills which involve the ability to apply the knowledge when the need arises to real systems rather than traditional imaginary examples. The evaluation process should be based on the award of credits to those students who develop the capability to apply scientific principles when the need arises in industry. An industry involves the conversion of raw materials to useful product(s). If the manufacturing process is carried out at a constant pressure the Gibbs free energy change ($\ddot{A}G^0$) is mostly a positive value.

The natural Industry is the photosynthesis which produces useful carbohydrates.



Since the Gibbs Free energy change is positive external energy (solar energy) is essential to push the reaction forward. Therefore, thermodynamics is applied to photosynthesis. Not only thermodynamics, but also quantum mechanics which involves an electron transfer from HOMO to LUMO in the photosynthesis. This is an example of a 'Natural Industry'.

A list of some Industries in Sri Lanka is given below:

1. Paper and Pulp Industry
2. Leather Industry – Tanneries
3. Metal Pickling Industry – Steel
4. Electroplating Industry
5. Milk Processing Industry – Dairies
6. Sugar Processing Industry
7. Food Processing Industry – Desiccated coconut, Foot canning, Mineral water bottling
8. Textile Dying and Finishing Industry
9. Petroleum Refinery
10. Pesticide Packing Industry
11. Rubber Processing Industry
12. Various other Industries

The application of chemistry is not only for the manufacturing process but also associates with environmental standards in their management processes. Some standards for the discharge of industrial effluents are listed below:

Central Environmental Authority

Ambient Water Quality Standards for Irrigation and Agriculture

Parameters	Unit	Standard
Total Dissolved Solids	mg/l	500
Conductivity	dS/m	0.7
Sodium Adsorpton		6-15
pH		6.0 – 8.5
Dissolved oxygen	mg/l	3
BOD	mg/l	5

No.	Determinant	Tolerance limit for effluents discharged into surface waters	Tolerance limit for effluents discharged into marine coastal waters	Tolerance limit for effluents discharged into land for irrigation
1	pH	6.0 – 8.5	6.0 – 8.5	5.5 – 9.0
2	Temperature ^0C	40	45	35
3	BOD mg dm^{-3}	60	100	250(100)
4	COD mg dm^{-3}	400 (250)	400 (250)	650 (300)
5	Chloride mg dm^{-3}	1000	Not applicable	-
6	Chromium (VI) mg dm^{-3}	0.5	0.5	0.5
7	Chromium (total) mg dm^{-3}	2.0	2.0	2.0
8	Sulphate mg dm^{-3}	2.0	5.0	-

If the environment is affected it creates an undesirable effect on society. As the students of chemistry are part of the society they should be able to understand the units given in the standards and used by the society.

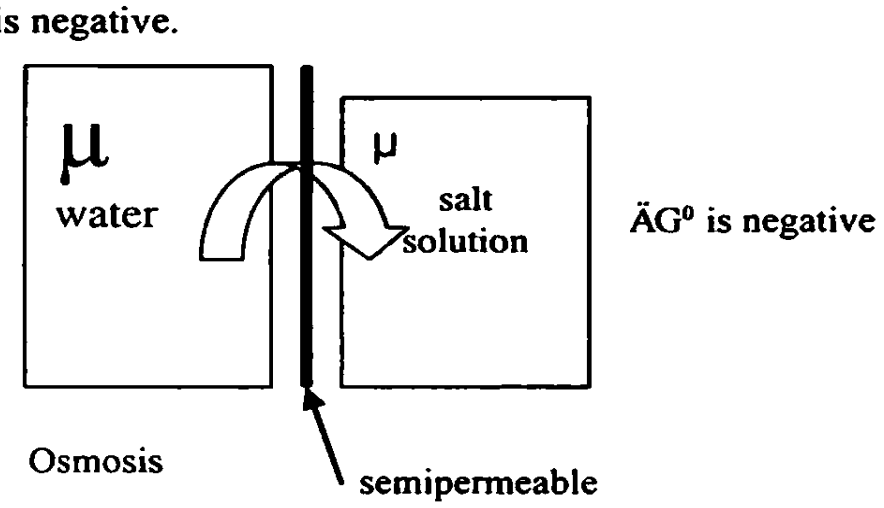
The following examples illustrate the units.

50 mg dm^{-3} of NO_3^- ≡ $8x10^{-4}$ mol dm^{-3} ≡ 11.3 mg dm^{-3}

of NO_3^- – N ≡ 0.008 cmol dm^{-3}

200 mg dm^{-3} of Ca^{2+} ≡ $5x10^{-3}$ mol dm^{-3} ≡ $1x10^{-2}$ cmol dm^{-3}

Another useful phenomenon in biology and physiology is osmosis, which is the movement of water molecules from an area of low concentration to an area of high concentration. The salt concentration of a plant or animal cell is very high and cell membranes are completely permeable to water. When a cell is placed in a solution of low concentration (*e.g.* distilled water) the water diffuses into the cell, causing the death of the cell. When a salt is dissolved in pure water the chemical potential (i) of the pure water decreases. This leads to the spontaneous movement of water molecules through the semi-permeable cell membrane since the Gibbs free energy change for this movement is negative.



$$-RT \ln x_x = \int_p^{p+\Pi} V_m^* dp$$

The pure solvent has thermodynamic tendency to flow into the solution

When pressure is applied against the direction of osmotic movement then the osmotic flow will be slowed or even reversed (reverse osmosis). When the pressure is just enough to stop the osmotic flow an equilibrium is reached. This is called the 'Osmotic Pressure'. It is obvious that chemistry plays a vital role in all aspects of biology and physiology (medicine). There are several examples of this nature where the principles of chemistry can be meaningfully applied. The teaching of chemistry should be geared in such a way that students will develop the capability to apply chemical principles to industry, medicine (physiology), laboratory and even day to day life.

3. 'Literacy' in Chemical Education

Over 90% of Sri Lankans possess the ability to use the language of words. Similarly, over 90% of students who learn chemistry as a subject possess the ability to reproduce the subject matter as it is. Should we claim that the 'literacy' of chemical education is over 90%? Chemical education is the transfer of knowledge /

skill in chemistry from the teacher to the student. The transfer is inadequate if the student does not possess the ability to use the knowledge/skill when the need arises. The ability to use the knowledge/skill in chemistry when the need arises is considered as the 'literacy' in chemical education.

An average student will not automatically develop the ability to use the knowledge/skill when the need arises unless he practices. It is like any other activity in life *e.g.* driving a car, a student has to practice to develop this ability. The most important way that an average student will develop this ability is by 'self learning' after the knowledge is transferred from the teacher. The best self learning is the reading of text-books. An average student may be required to read the text-books several times to achieve a proper understanding of the principles he learnt. Even though the time required for such a process varies from student to student it will not only be helpful for a student to gain a better knowledge in chemistry but also be useful to acquire the ability to use the knowledge in chemistry when the need arises. Since it is a very slow process it has to be initiated at least at the secondary level of education. A student who has undergone the training of this self-learning practice, after the completion of his learning of chemistry will be a citizen who possesses a great potential to contribute towards the economic development of the country.

Is the 'literacy' in chemical education achieved today? Today the self-leaning aspect of chemistry is not popular among students who read chemistry as a subject due to,

(i) the inadequacy of reading materials in chemistry written in the language of instruction, and
(ii) the popular examination oriented study prevailing among students who only study the answers to a particular set of questions.

One such example is the concept of partial pressure which is taught extensively at G.C.E. (A/L) to apply to imaginary situations (question 5, Essay paper). However, most students find it difficult to apply the concept of partial pressure to the environment. They are only familiar with the imaginary situation given in the questions. The simple question asked is 'What is the approximate partial pressure of oxygen in the atmosphere which is required for comfortable breathing?' This cannot be answered by many students even if they are capable of calculating the partial pressure of very complicated imaginary systems such as a closed vessel with injected helium *etc*. The answer to this incapability is that the approximate partial pressure of oxygen in the atmosphere is **not an examination question** which eternally appears in question 5 of the essay paper. This clearly indicates that, an average student does not possess the ability to apply chemical principles to industry, environment or even day to day life. An average student who learnt chemistry as a subject is not 'literate' with the subject of chemistry.

4. Curricula and Evaluation.

In order to achieve the National Goals the curriculum at G.C.E.(A/L) should cater to the 97% of the students who do not gain admission to Universities in Sri Lanka. At present, the course content in chemistry is geared for the minority (3%) who enter the universities. In many developed countries, personnel who have written and published books for the secondary level are not allowed to participate in the designing or the revision of the course content. This is because the **vested** interest inadvertently predominates over the **National** interest. Since there is no such rule in Sri Lanka the students who offer chemistry at G.C.E.(A/L) do not find any usefulness of the subject if they fail to gain admission to the Universities. Sri Lanka suffers because the vested interest predominates over the national interest. A frequent revision of the curricula is essential to suit rapid changes in some aspects of chemistry. It is suggested that a permanent body should undertake revision of the curriculum of chemistry at G.C.E. (A/L) after conducting research on the aspects of catering to 97% of the students. This is cost effective since it helps in the development of the economy of the country.

The fundamental principles in chemistry should be taught thoroughly with at least one application of each principle. The evaluation should be based on testing the ability of the student to apply the principle to a different situation which **has not been taught. The credit given at the examination** should be based on their ability to use the knowledge and not the ability to memorize the learnt materials. This is a difficult task for the examiners. However, it helps in the development of the economy of the country.

5. References

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(ii) C Dahanayake and H D Gunawardhana (1998) Tertiary Education in the Physical Sciences *J Natn Sci, Coun. Sri Lanka,* **26:** 217

Membership News

Prof. H D Gunawardhana was inducted on 11th January 2008 as the General President of the SLAAS for 2008. He was also nominated to serve on the ICSU Committee of the NSF as an expert scientist on Environment. He is also the Chairman of Sri Lanka Accreditation Board for Conformity Assessment (SLAB).