R Gopalan
Department of Chemistry, Madras Christian College, Tambaram, Chennai 600 059, India.

Small is Beautiful, in Chemistry Also[1]

Chemistry is very much an experimental science. Students can appreciate the various concepts of chemistry only by conducting laboratory experiments. This is the reason for the schedule of many hours of practical work for the B.Sc and M.Sc chemistry courses. These experiments necessarily involve the use of a large number of chemicals that are used and washed down the sink. This implies more expenditure for laboratory work in chemistry than for any other subject.

The prices of chemicals have increased phenomenally during the last few decades (*Table 1*). However, the laboratory budget in our educational institutions has not been enhanced in proportion to the price-hike for chemicals. This imbalance between the prices and budget has led to a considerable qualitative and quantitative decrease in chemistry practical experiments in most of the educational institutions in our country. Only a few experiments prescribed in the syllabus are actually conducted by the students in the chemistry course. In several colleges post-graduate students do only three or four experiments in a year, implying a serious erosion in the quality of chemistry education.

There is, therefore, an urgent need to circumvent this deficiency in the chemistry laboratory work. An excellent way to solve this crisis involves miniaturizing the chemistry experiments. Each experiment has to be planned using micro quantities of the chemicals involved. This would require replacement of the currently used glassware by micro glassware. Initially, such replacements would mean a substantial budget allocation. Therefore, this replacement can be effected in a phased manner in two or three years. The adoption of micro-scale methods would save a lot of money, which in the long run would be manyfold compared to the initial expenditure incurred on new micro glassware.

Several advantages would accrue on switching over from the present macro scale to the microscale of experimentation:

[1] Based on a paper presented at the National Seminar on Chemical Education and Research, held at the Loyola College, Chennai in November 1995.

Figure 1 Weighing Funnel. This can be used for weighing a substance (instead of using a weighing bottle) and also as a funnel. It is beak-shaped with a hollow stem.

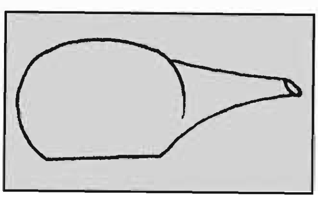


Table 1 Comparative prices in India of some chemicals over the last 30 years. (All prices in Rupees for 500 g/500 ml package)

Chemicals	1965	1976	1984	1994
Ammonium Thiocyanate	10	38	50	90
Ferrous Ammonium Sulphate	5	9	26	66
Calcium Chloride	2	4	23	48
Cadmium Nitrate	22	58	100	540
Copper Sulphate	4	22	49	95
Potassium Iodide	27	77	255	510
Potassium Nitrate	3	11	30	60
Potassium Permanganate	6	16	45	110
Potassium Dichromate	6	20	57	160
Sodium Acetate	5	15	36	68
Glacial Acetic Acid	4	14	24	58
Aniline	8	26	46	150
Benzaldehyde	13	55	65	175
Fehling Solution B	4	14	35	130
Glycerol	7	35	47	125
Nitrobenzene	4	20	32	108
Silver Nitrate	99	625	3350	6200
Cobalt Sulphate	17	60	328	1150
Potassium Ferrocyanide	5	15	113	230
Potassium Ferricyanide	11	35	113	400
Nickel Sulphate	3	24	52	300
Fehling Solution A	1	5	20	85

This table is quoted from K V Sane, Effective Techniques for Improving Laboratory Teaching, *Chemistry Education*, April-June, p.6, 1995.

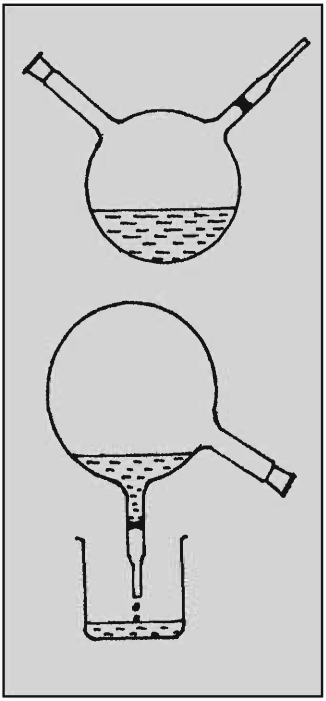


Figure 2 Two-necked flask for small-scale crystallization and hot filtration. It has a sinter fused into one arm. This is suitable for a variety of organic laboratory operations, to be used with an air condenser, a Liebig condenser or as such.

- Handling smaller apparatus and lesser chemicals requires greater skill in students; therefore, the chemistry practical work would be more challenging than what it is now. It would also impart a better training for them.

- Larger number of experiments for each class can be prescribed with the same budget.

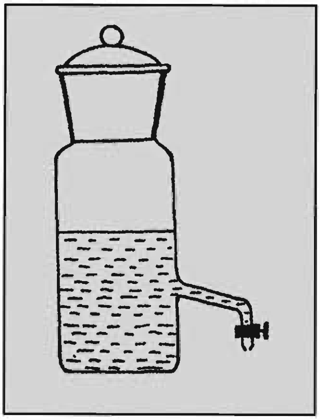
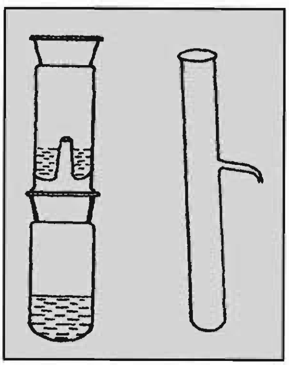


Figure 3. Liquid weighing bottle. It has a side-arm with a stop-cock for draining a liquid. There is a hole in the neck and another hole in the hollow stopper. These two holes are made concentric by turning the stopper for drawing the liquid through the stop-cock. The bottle is weighed before and after drawing the liquid into a receiver to know the weight of the liquid drawn.



Figures4&5 (left) Micro distillation unit for liquids of a few ml quantity(right) Micro distillation tube for liquids less than 1 ml.

- Cleaning, drying and maintenance of the microsized glassware would be easy and convenient.

- The cost of replacing smaller, broken glassware would be less than that of large glassware.

- The micro apparatus set requires smaller strorage space and therefore the laboratories can be better organized and used by more students than what is being done now.

- Students, using only small quantities of chemicals, would be less exposed to health hazards.

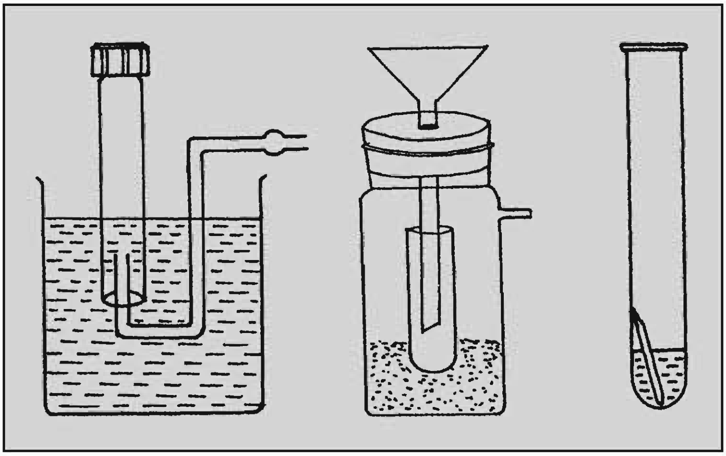
- The pollution of the laboratory during the practical class and also the pollution of the environment from the laboratory wastes would be substantially reduced.

- The quantity of fuel needed for heating the reactants can be lessened.

Chemistry teachers, who traditionally prescribe large scale use of chemicals, may find it difficult to accept this concept of miniaturization of experiments. Some of them may argue that this would sacrifice the quality or accuracy of the results. But microscale experiments prepare the students for modern research, which generally involves handling chemicals in milligram quantities. Of course, teachers need to be innovative to utilize the advantages of miniaturized equipment.

Small is not only beautiful but also rewarding both for the teachers and the students. Failure to adopt miniaturization would mean continued fall in the standard of chemistry laboratory work, as the prices of the chemicals are only expected to rise further without any proportionate rise in the laboratory budget.

Any conventional laboratory glassware can be miniatured. For example, enormous quantity of chemicals can be saved using



Figures 6-8 (left) Gas collection This can be used for collecting and testing small quantities of gases such as CO_2, H_2S, SO_2, hydrocarbons, etc. (center) Micro filter assembly. This is suitable for filtration of 1-3 ml of material. (right) Micro boiling point apparatus. A mixture of 0.5 ml of the substance is sufficient for determining the boiling point. (The method is described in B N Campbell and M Mecarthy Ali, Organic Chemistry Experiments. Brooks/Cole. Pub. Co. California. p.83, 1994).

semi-micro test tubes of 5mm inner diameter and 80mm height. An elongated tube (without a bulb) with 25mm diameter and 150mm length would serve as a separating funnel. Melting points can be determined using semi-micro Thiele tube of 25ml capacity. Glass spatula can be made from glass rods by forming a cavity at one end.

Some representative items in the miniature chemistry kit are shown in *figures 1-8* each with a brief description.

Micro-scale labware has already been tried out in a few institutions, e.g. University Department of Chemistry at Poona by S L Kelkar. Pioneering effort in optimising the kit and preparing a handbook describing a number of experiments which can be carried out is going on in the Educational Technology Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, Bangalore 560 064. Further information can be obtained from K V Sane at the above address.

J Chandrasekhar

Suggested Reading

- D W Mayo, R M Pike and S S Butcher. *Microscale Organic Laboratory*. John Wiley and Sons. New York, 1986.
- Z Szafrom, R M Pike and M M Singh. *Microscale Inorganic Chemistry: A Comprehensive Laboratory Experience*. John Wiley and Sons. New York, 1991.