

# PROJECTS

## BACKGROUND INFORMATION ABOUT INVESTIGATORY PROJECTS

### INTRODUCTION

The expansion of scientific knowledge and consequently the change in the system of education has led to a modification in the methods of instruction. Today the stress is laid on inquiry approach and discussion method instead of the age-old lecture method of teaching. A new dimension in the teaching of science has been added by including the project-work at the higher secondary level. Teaching through project work is an individualized instructional technique. It provides an opportunity to the student to define a problem, to plan his/her work, to search appropriate resources, to carry out his/her plans, and to draw conclusions. This way, students are exposed to the fundamental scientific principles, methods and processes and get a first hand knowledge about the various phases involved in a scientific investigation. Thus the project work helps to: (a) stimulate interest in science; (b) arouse scientific curiosity; (c) develop independent critical thinking; (d) provide experience of using various tools and techniques in the field of science and (e) develop self-confidence. The modern trend in the teaching of science therefore encourages more project work.

Any kind of investigation; formulated, designed and carried out in the library, laboratory, in the field, or at home constitutes an investigatory project. A project may be as simple as collection of samples of minerals and it may be as difficult as developing an original indigenous process for the production of a chemical. Some of the projects can be completely theoretical and involve only the library work. Others may involve the experimental work to be carried out in the laboratory. The experimental work in science exposes the students to a number of scientific instruments, tools, techniques and intellectual skills.

### SELECTION OF PROJECTS

Projects should usually be selected by the students. The idea of a project originates from studying a subject in the classroom, reading the reports of various projects, science news, popular science articles from science journals etc. Sometimes the idea of a science project may strike during classroom discussion on topics, which may require testing, quantifying and interpreting. Some of the science journals for getting the ideas for a project are : (a) Journal of Chemical Education; (b) Chemistry Education; (c) Education in Chemistry; (d) New Scientist; (e) School

Science; (f) School Science Review; (g) Science; (h) Scientific American; (i) School Science Resource Letter, etc. Once the project work begins, it might provide new titles and ideas.

In spite of the availability of the above listed scientific literature, it should not be assumed that students can begin the work on projects spontaneously. Since majority of the science journals listed above are not available in Indian Schools. Students need the help and guidance from the teacher. If some student does not get an idea for the project, the teacher may provide a list of suggested projects or take the students to science fairs and exhibitions to show what other students are doing. A format for working on the projects is given below:

1. Title of Project
2. Objectives and importance of Project
3. A brief outline of work on Project

The title of the project should be written in such a manner that the objectives and importance of the project is clearly defined. In other words a project title and its objectives should create an interest and curiosity. A 'brief outline of working on a project' helps the student to initiate the work.

It may be debatable that this approach of suggesting ideas for the projects defeats one of the basic objectives of project work, namely originality, but providing guidelines to the students is completely scientific and desirable to encourage every student to begin and aim at something in the first attempt.

### MANAGING TIME

Central Board of Secondary Education has allocated ten periods for the project work. A student can start the project right in the beginning of the academic year and can carry it out in phases and submit the report of the project at the end of the year.

### TECHNICAL AND ACADEMIC GUIDANCE

This is an important factor in the smooth running of the project work. The student should plan for the project well in advance and discuss its design with the teacher. If improvisation of the apparatus or some instrument is needed or a chemical is not available in the laboratory. The help of teacher may be taken. If some technical or academic guidance is required help may be taken not only from the concerned teacher of chemistry but also from physics from and other science teachers as well.

### LABORATORY FACILITIES

The selection of the project should be such that as far as possible, the material (apparatus, instruments, chemicals, etc.) needed for the project-work is easily available. Student may purchase the affordable chemical or an apparatus (improvised or original) if it is not available in the laboratory, and the student is very curious to take up the project and wants to do it. The students should be discouraged from taking highly expensive projects. An effective project-work requires an integrated approach rather than a subject specific approach.

The project work in the laboratory requires a bigger and separate space. Arrangements should be made in such a way that at a given time all the students are not involved in doing the laboratory work. Some students should carry out the work of collecting references in the library while others should design experiments.

Problems may arise in carrying out the long term experiments like corrosion, fermentation etc. in the laboratory. It is suggested to have a separate bench in the laboratory, where long term experiments can be set up. For storing the samples of certain chemicals and apparatuses relevant to the project-work, cardboard boxes, with student's name written on them can be used. Empty bottles, if available, can also serve the purpose of storing the chemicals.

### RECORDING THE PROJECT WORK

Recording the actual observation in the project work is very essential. Students should be encouraged to record the negative results also. A general format for writing the project report is suggested below. It should involve the following points :

1. Title of project reflecting objectives
2. Principles used for Investigation
3. Apparatus and Chemicals required
4. Improvisation, if any
5. Procedure
6. Observations and Calculations
7. Conclusions and the logic upon which the conclusions are based
8. Precautions
9. Suggestions for further investigations, if any

To illustrate the format outlined above, a 'sample project' report is presented in the end. It may further be noted that sample project report serves merely as a guideline to the

students while writing their projects. It is by no means exhaustive and is open to further improvements. Brief outline of some projects is given below.

## PROJECT 1

### Title

To test the contamination of water by bacteria by checking the sulphide ion concentration and find out the cause of contamination.

### Objective

To check the bacterial contamination in samples of water collected from different sources by determining sulphide ion concentration.

### Background Information

Sulphide ions are present in water when anaerobic bacteria decompose organic matter or reduce sulphates. These are found in stagnant water. Generally pollutants from paper mills, gas works, tanneries, sewage works and other chemical plants are responsible for the growth of such bacteria.

### Brief Procedure

#### Collection of Samples

Sulphides are readily oxidised, therefore care should be taken at the time of sampling to exclude air by flushing it with nitrogen or carbon dioxide. But the best way is to 'fix' the sample immediately after collection. This can be done by adding small volume of cadmium-zinc acetate solution. For this take 80 mL of water and add cadmium-zinc acetate solution 20 mL to obtain a total volume of about 100 mL. To make Cd-Zn acetate solution dissolve 50 g cadmium acetate and 50 g zinc acetate in 1.0 L of water. If collected sample is acidic in nature, then first neutralize it with little excess of alkali.

#### Titration of Fixed Solution

Take 100 mL fixed solution in a titration flask, add 20 mL 0.025 M iodine solution and immediately add 15 mL, (1:1) HCl and mix. Titrate the excess iodine against 0.05 M  $\text{Na}_2\text{S}_2\text{O}_3$ , adding starch solution as indicator towards the end point. Calculate the amount of sulphide ions in the original samples from the amount of iodine used in the reaction with  $\text{H}_2\text{S}$ . Subtract the values of blank titration if available from the calculated values.

**PROJECT 2****Title**

To study the methods of purification of water.

**Objectives**

- To study level of purity achieved by using different methods of purification.
- To study advantages and disadvantages of using different method for purification.
- To know about specific uses of pure water.

**Background Information**

Purity of water obtained from different natural sources is different. The type of contamination and impurity present depends upon the source from which water is obtained. Besides drinking purposes, we require pure water for various other purposes e.g. in chemical analysis. There are various methods for the purification of water. These remove impurities and contamination to different extent. There are some advantages and disadvantages in using these methods. Comparison of various methods of purification will provide an idea about obtaining water of specific purity for a specific purpose.

**Brief Procedure**

Students may find out level of purity achieved by various techniques in use, for the purification of drinking water. They can survey the literature and visit industries etc. to find out uses of water of specific purity. Students may work in groups for the study of various aspects of the project.

**Note :** Another aspect of the project may be to study different methods of purification of water taken from different sources such as river, well, bore-well, municipality etc.

**PROJECT 3****Title**

Testing the hardness, presence of iron, fluoride, chloride etc. in drinking water obtained from different regions and a study of the cause of presence of these ions above permissible limits.

## Objectives

- To test the total hardness, iron, fluoride and chloride etc. in different samples of water.
- To collect information about local sources of above ions in water.
- To study the effect of these ions on health if present beyond permissible limits.
- To find out whether any such problem exists in the locality and around.

## Background Information

Quality of drinking water has direct relationship with the human health and life. If iron, fluoride, chloride etc. are present in water above permissible limits, they may cause several health problems. For example, if fluoride is present above permissible limit, people of the region may suffer from fluorosis. Hardness of water is due to the presence of calcium and magnesium ions. It is well known fact that hard water is not fit for laundry purposes. Thus, it is very important to know the ions and their amount present in water.

## Brief Procedure

Students may collect samples of water from different sources. They can detect the presence of different ions by usual methods of analysis. Total hardness of water can be estimated by standard procedure of complexometric titration. Estimation of  $\text{Cl}^-$ ,  $\text{F}^-$  and  $\text{Fe}^{2+}$  is difficult at this level. Therefore existing data from approved labs can be taken for the purpose of investigation.

## PROJECT 4

### Title

Investigation of the foaming capacity of different washing soaps and the effect of addition of sodium carbonate on their foaming capacity.

### Objective

To study the foaming capacity of soaps and the effect of addition of sodium carbonate on their foaming capacity.

### Brief Procedure

Weigh 1 gram of a sample of soap and dissolve it completely in 100 mL of distilled water. Take 10 mL of the soap solution in a boiling tube close the mouth of the boiling tube with the help of a cork and shake the solution making 20 regular strokes so that foam increases uniformly. Measure the length of the boiling tube up to which the foam rises. Similarly, perform the experiment with other soap solutions.

Dissolve 0.5g of sodium carbonate in 50 mL of each of the above soap solutions separately. Now take 10 mL of a solution in a boiling tube and shake it equal number of times (e.g. 20 regular strokes). Measure the length up to which foam appears. Similarly, perform the experiment with other soap solutions. Record the observations in a tabular form.

Compare the height upto which foam produced rises in different soap solutions with and without the presence of  $\text{Na}_2\text{CO}_3$  and draw conclusions.

## PROJECT 5

### Title

Study of the acidity of different samples of tea leaves and reasons for the variation in colour of tea prepared from these leaves.

### Objective

To estimate the concentration of acids present in different tea samples and the effect of addition of acids or bases on the colour of tea extract.

### Brief Procedure

#### (a) Estimation of Concentration of Acids Present in Tea

Weigh 10 grams of the sample of tea leaves and prepare the extract of each sample separately in 200 mL of distilled water. For this, boil different samples of tea leaves with distilled water 8 for a fixed time period.

Take 5mL of tea extract in a conical flask and dilute it with 20 mL of distilled water. Shake the solution well for homogenous mixing and then titrate it against M/50 NaOH solution using phenolphthalein as an indicator. Similarly, titrate other tea



extracts with M/50 NaOH solution. Calculate the concentration of acids present in different samples of tea leaves in terms of molarity. If colour of the extract causes problem, then tea extract can be taken in the burette and sodium hydroxide solution in the conical flask. Phenolphthalein may be used as an indicator if sodium hydroxide solution is taken in conical flask. The colour change will be from pink to colourless.

### **(b) Effect of Acids and Bases on the Colour of Tea Extract**

Take five filter paper strips and mark them as A, B, C, D and E. Dip all the strips in any one sample of tea extract and then take them out. Now put two drops of dilute HCl, acetic acid solution, NaOH solution and  $\text{NH}_4\text{OH}$  solution on strips A, B, C and D respectively. Compare the change in colour of these strips with reference to the colour of the strip E. Repeat this experiment with other samples of tea extract.

## **PROJECT 6**

### **Title**

Study the rates of evaporation of different liquids

### **Objective**

To study the relationship between the rates of evaporation of different liquids and their chemical constitution.

### **Brief Procedure**

Take five clean and dry weighing tubes and mark them as A, B, C, D and E. Weigh each weighing tube with its stopper. Now pour 10 mL of different liquids (ethanol, ether, tetrachloromethane, acetone etc.) in different weighing tubes. Weigh each weighing tube again and find the mass of the liquid taken in each weighing tube.

Remove the stoppers of the weighing tubes and keep them at room temperature for one hour. After exactly one hour, close the mouth of all the weighing tubes with their stoppers and weigh them again one by one.

Calculate the loss in mass of each liquid. The temperature and the surface area should be the same for the evaporation of each liquid. Determine the rate of evaporation of each liquid in grams of liquid evaporated per second. Relate the difference in rates of evaporation of liquids with their chemical constitution and variation in intermolecular/intra-molecular interactions.



**PROJECT 7****Title**

Study the effect of acids and alkalies on the tensile strength of fibres

**Objective**

To study the effect of acids on the tensile strength of different types of fibers.

**Brief Procedure**

The tensile strength of a fibre is measured by noting the minimum weight required just to break the thread. It may be done as follows:

Take a thread of about 20 cm length and tie its one end with a ring fixed on the iron stand and the other end with a hanger which carries the weights. Increase the weight on the hanger and find out the minimum weight required to just break the thread. Repeat the experiment with threads of equal length and thickness but of different materials (eg. cotton, wool, silk, terylene etc.). These weights are the measure of tensile strength of the fibre.

The effect of acids and alkalies on the tensile strength of fibres can be determined by dipping them separately in dilute HCl or dilute NaOH solution of equal strengths for equal intervals of time. After a small but fixed interval of time, the fibres are removed from the solution, washed with water and dried. Then minimum weight required to just break these threads are determined. These weights are the measures of the tensile strengths of fibres after treatment with acid or alkali. Interpret your observations in terms of chemical constitution of the material of fibre.

**PROJECT 8****Title**

Study of the acids and mineral contents of vegetables and fruits.

**Objective**

- (a) To determine the amount of acids present in various vegetables and fruits.
- (b) To detect the presence of iron, carbohydrate, protein and sugar etc. in vegetables and fruits.

## Brief Procedure

### (a) Acid Content

Take out the juice of a few fruits and vegetables (apple, orange, amla, lemon, raddish, cane sugar etc.) by crushing them. Keep the juice samples in different containers. Determine the pH of different samples of juices. Determine their acid content by titrating a known quantity of juice with M/100 potassium hydroxide solution using phenolphthalein as an indicator. In case of dark coloured juices, dilute them with enough distilled water to get sharp end point during titration.

Compare the acid contents of juices by comparing their acid values. Acid value of vegetables and fruits is the number of milligrams of potassium hydroxide required for neutralizing the acids present in one gram of vegetable/fruit.

### (b) Tests for Iron, Carbohydrate (starch and sugar), Protein and Fats

Test the vegetables and fruit juices for the presence of iron. Heat the vegetable juice with concentrated  $\text{HNO}_3$  for some time and perform the test for iron. Carbohydrate (starch, sugar), protein and fats can be tested by the usual tests.

## SAMPLE PROJECT REPORT

### Title

A study of the variation of viscosity of organic compounds of same homologous series with variation in the (a) molecular masses and (b) structures of carbon chains.

### Background Information

Some liquids like honey or Mobil oil flow very slowly while others like water or kerosene flow rapidly. Liquids that flow slowly are known as viscous liquids while others that flow rapidly are known as non-viscous liquids. The resistance offered by a liquid to flow is known as viscosity. It is related to intermolecular forces existing in a liquid. Different liquids have different values of viscosity due to the existence of different magnitudes of intermolecular forces. The comparison of viscosities of various homologues and isomers in a particular homologous series would give an idea about the magnitude of intermolecular forces existing in them.

## Objectives

The objectives of this project are to establish a relationship between (a) viscosity and molecular masses; and (b) viscosity and nature of carbon chain in organic compounds.

## Principle Involved

The resistance to flow offered by a liquid is measured in terms of coefficient of viscosity which is defined as follows:

‘Coefficient of viscosity of a liquid at a specified temperature is the steady force required to maintain a velocity difference of unity between two parallel layers of a liquid, a unit distance apart and having a unit area of contact’. Coefficient of viscosity is measured by Ostwald viscometer method. For two liquids whose coefficient of viscosity are  $d_1$  and  $d_2$ ,  $\eta_1$ ,  $\eta_2$  the time of flow in seconds are  $t_1$  and densities are  $d_1$  and respectively  $d_2$  then the following relation holds:

$$\frac{\eta_1}{\eta_2} = \frac{d_1 \times t_1}{d_2 \times t_2}$$

Hence if the viscosity of one liquid is known, the viscosity of other can be determined.

### Hazard Warning

- Acetone and alcohols are inflammable, do not let the bottles open when not in use.
- Keep the bottles away from flames.
- Wash your hands after use.
- Wear safety spectacles.

## Material required

Ostwald viscometer, stop-watch, beaker (250 mL), pipette, graduated cylinder, kerosene, petrol, diesel, methyl alcohol, ethyl alcohol, propyl alcohol, isopropyl alcohol, butyl alcohol, isobutyl alcohol, tert butyl alcohol and amyl alcohol.

## Brief Procedure

The viscometer was washed, rinsed with alcohol and dried. 10 mL of the liquid under investigation was filled in it and the time required for the flow of liquid between two marks of viscometer was noted with the help of a stop watch. These observation were recorded in Tables I and II. The viscosities of various liquids were calculated by the formula discussed under the heading principles involved.

## Observations and Calculations

Room Temperature = 23°C.

A viscometer of different capacity was used for alcohols.

**Table 1 : Data for the time of flow of various compounds**

Sl. No.	Name of the compound	Time of flow (seconds)	Density (g/mL)	Viscosity (millipoise)
1.	Water	13.5	1	10.08
2.	Petrol	8.5	0.8	6.4
3.	Kerosene Oil	22.0	1	16.4
4.	Dileseel Oil	48.0	1	18.0

**Table 2 : Data for the viscosity vs molecular mass relationship of various compounds**

Sl. No.	Name of the compound	Molecular mass	Time of flow (Seconds)	Density in (g/mL)	Viscosity (millipoise)
1.	Water	18	180	1	10.08
2.	Methanol	32	136	0.79	7.6
3.	Ethanol	46	258	0.78	14.4
4.	Propan-1-ol	60	391	0.8	21.9
5.	Propan-2-ol	60	546	0.79	30.6
6.	Butan-1-ol	74	612	0.81	34.3
7.	Butan-2-ol	74	686	0.80	38.4
8.	2-Methlprapan-1-ol	74	1406	0.79	78.8
9.	Pentan-1-ol	88	784	0.817	43.9

**Note :** \* If the homologues/isomers of alcohols are not available, other suitable compounds, which are available or are easily manageable can be used for this study.

\*\* Time of flow recorded in the tables are specific for a viscometer and should not be taken as standard values.

## Conclusion

As seen from the Table 1, the viscosities of various hydrocarbon fractions, i.e. petrol, kerosene and diesel oil are on an average 6.4, 16.4 and 18.0 respectively. Since the molecular mass of these fractions increases from petrol to diesel oil, this indicates that viscosity increases with increase in molecular mass. The intermolecular attractions tend to increase with increase in molecular mass.

In the case of alcohols, the viscosity of nine alcohols were determined and their values are given in Table-II. The viscosity of alcohols increases with an increase in the molecular mass as can be seen from the viscosities of methanol, ethanol, propan-1-ol, butan-1-ol, the viscosities are 34.3, 38.4 and 78.8 millipoise respectively. This shows that viscosity increases with the increase in molecular mass.



### Precaution

The viscometer should be thoroughly cleaned and dried before use.

### Suggestions for further investigation

A study of the variation of viscosity with intermolecular forces may be carried out using appropriate compounds.

### References

KEENAN, C.W.; WOOD, J.H. *General Chemistry IVth Edition.*, Harper and Row Publishers Inc. New York.

# APPENDICES

## APPENDIX I

### ARRANGEMENT OF REAGENTS IN THE LABORATORY

Laboratory assistants must see that the reagent bottles on each shelf are properly arranged, labelled and contain sufficient quantity of the freshly prepared reagents.

#### 1. Reagents to be placed on the shelf of each seat

Reagents kept in narrow-mouthed stoppered bottles

- |                              |                           |
|------------------------------|---------------------------|
| 1. Ammonium carbonate        | 5. Lime water             |
| 2. Ammonium hydroxide        | 6. Nitric acid (dil.)     |
| 3. Hydrochloric acid (dil.)  | 7. Sulphuric acid (dil.)  |
| 4. Hydrochloric acid (conc.) | 8. Sulphuric acid (conc.) |

#### 2. Reagents to be placed on common shelf

##### (A) Solutions kept in narrow-mouthed stoppered bottles

- |                                |                              |
|--------------------------------|------------------------------|
| 1. Acetic acid (glacial)       | 19. Lead acetate             |
| 2. Acetic acid (dilute)        | 20. Magnesium sulphate       |
| 3. Alkaline- $\beta$ -naphthol | 21. Mercuric chloride        |
| 4. Ammonium molybdate          | 22. Methyl orange            |
| 5. Ammonium oxalate            | 23. Nessler's reagent        |
| 6. Ammonium sulphate           | 24. Phenolphthalein          |
| 7. Ammonium sulphide (yellow)  | 25. Potassium chromate       |
| 8. Barium chloride             | 26. Potassium dichromate     |
| 9. Bromine water               | 27. Potassium ferricyanide   |
| 10. Calcium chloride           | 28. Potassium ferrocyanide   |
| 11. Calcium sulphate           | 29. Potassium iodide         |
| 12. Carbon disulphide          | 30. Potassium permanganate   |
| 13. Chlorine water             | 31. Rectified spirit         |
| 14. Cobalt nitrate             | 32. Silver nitrate           |
| 15. Copper sulphate            | 33. Sodium hydrogenphosphate |
| 16. Dimethyl glyoxime          | 34. Sodium nitroprusside     |
| 17. Ferric chloride            | 35. Stannous chloride        |
| 18. Ferrous sulphate           | 36. Starch solution          |
|                                | 37. Universal indicator      |

##### (B) Reagents kept in wide-mouthed bottles on common shelf

###### (a) Solids

- |                       |                              |
|-----------------------|------------------------------|
| 1. Ammonium chloride  | 8. Potassium dichromate      |
| 2. Borax              | 9. Sodium carbonate          |
| 3. Ferrous sulphate   | 10. Sodium hydrogencarbonate |
| 4. Fusion mixture     | 11. Sodium hydroxide         |
| 5. Manganese dioxide  | 12. Sodium nitrate           |
| 6. Oxalic acid        | 13. Sodium nitroprusside     |
| 7. Potassium chromate | 14. Sodium peroxide          |

###### (b) Metals

- |           |                  |
|-----------|------------------|
| 1. Copper | 3. Zinc granules |
| 2. Tin    | 4. Zinc powder   |

###### (c) Papers

- |                               |                              |
|-------------------------------|------------------------------|
| 1. Lead acetate paper         | 5. Starch iodide paper       |
| 2. Litmus paper (blue)        | 6. Starch paper              |
| 3. Litmus paper (red)         | 7. Turmeric paper            |
| 4. Potassium dichromate paper | 8. Universal indicator paper |

## APPENDIX II

### LIST OF CHEMICALS AND APPARATUS FOR CHEMISTRY LABORATORY

Sl. No. Inorganic Chemicals	Grade*	Sl. No. Inorganic Chemicals	Grade
1. Alum (potash)	L.R.	59. Mercuric chloride	L.R.
2. Aluminium chloride	L.R.	60. Methyl orange	A.R.
3. Aluminium sulphate	L.R.	61. Methyl red	A.R.
4. Ammonium acetate	L.R.	62. Nickel (II) nitrate	L.R.
5. Ammonium carbonate	L.R.	63. Nitric acid (conc.)	L.R.
6. Ammonium ceric nitrate	L.R.	64. pH paper and chart	—
7. Ammonium chloride	L.R.	65. Potash alumns	L.R.
8. Ammonium molybdate	L.R.	66. Potassium bromide	L.R.
9. Ammonium nitrate	L.R.	67. Potassium chromate	L.R.
10. Ammonium oxalate	L.R.	68. Potassium dichromate	L.R.
11. Ammonium phosphate	L.R.	69. Potassium ferricyanide	L.R.
12. Ammonium sulphate	L.R.	70. Potassium ferrocyanide	L.R.
13. Ammonium thiocyanate	L.R.	71. Potassium hydroxide	L.R.
14. Arsenious oxide	L.R.	72. Potassium iodate	L.R.
15. Barium chloride	L.R.	73. Potassium iodide	L.R.
16. Barium nitrate	L.R.	74. Potassium nitrate	L.R.
17. Bismuth nitrate	L.R.	75. Potassium nitrite	L.R.
18. Boric acid	L.R.	76. Potassium permanganate	L.R.
19. Bromine (liquid)	L.R.	77. Potassium sulphate	L.R.
20. Cadmium carbonate	L.R.	78. Potassium thiocyanate	L.R.
21. Cadmium chloride	L.R.	79. Schiff's reagent (or Fuchsin)	L.R.
22. Cadmium nitrate	L.R.	80. Silver nitrate	L.R.
23. Calcium carbonate	L.R.	81. Sodium acetate	L.R.
24. Calcium chloride	L.R.	82. Sodium bromide	L.R.
25. Calcium hydroxide	L.R.	83. Sodium carbonate	L.R.
26. Calcium hydrogenphosphate anhydrous	L.R.	84. Sodium chloride	L.R.
27. Calcium nitrate	L.R.	85. Sodium dihydrogenorthophosphate	L.R.
28. Calcium oxide	L.R.	86. Sodium dihydrogenphosphate	L.R.
29. Chlorine water	L.R.	87. Sodium hydrogencarbonate	L.R.
30. Cobalt nitrate	L.R.	88. Sodium hydroxide (flakes)	L.R.
31. Copper carbonate	L.R.	89. Sodium metabisulphite	L.R.
32. Copper sulphate	L.R.	90. Sodium metal	L.R.
33. Copper turnings	—	91. Sodium nitrate	L.R.
34. Cupric acetate	L.R.	92. Sodium nitrite	L.R.
35. Cupric nitrate	L.R.	93. Sodium nitroprusside	L.R.
36. Disodium tetraborate	L.R.	94. Sodium oxalate	L.R.
37. Ferric alum	L.R.	95. Sodium peroxide	L.R.
38. Ferric chloride	L.R.	96. Sodium potassium tartarate (Rochelle's salt)	L.R.
39. Ferrous ammonium sulphate	L.R.	97. Sodium sulphate	L.R.
40. Ferrous sulphate	L.R.	98. Sodium tartarate	L.R.
41. Ferrous sulphide	L.R.	99. Sodium thiosulphate	L.R.
42. Hydrochloric acid (conc.)	L.R.	100. Stannous chloride	L.R.
43. Hydrogen peroxide	L.R.	101. Starch (soluble)	L.R.
44. Iodine	L.R.	102. Sulphanilic acid	L.R.
45. Iron filings	L.R.	103. Sulphur	L.R.
46. Lead acetate	L.R.	104. Sulphuric acid, (commercial)	L.R.
47. Lead chloride	L.R.	105. Tin metal	—
48. Lead nitrate	L.R.	106. Universal indicator solution/paper	L.R.
49. Liquor ammonia	L.R.	107. Uranyl zinc acetate	L.R.
50. Litmus solution	—	108. Zinc acetate	L.R.
51. Magnesium bromide	L.R.	109. Zinc carbonate	L.R.
52. Magnesium carbonate	L.R.	110. Zinc chloride	L.R.
53. Magnesium chloride	L.R.	111. Zinc metal (granulated)	—
54. Magnesium ribbon	L.R.	112. Zinc oxide	L.R.
55. Magnesium sulphate	L.R.	113. Zinc sulphate	L.R.
56. Manganese dioxide	L.R.		
57. Manganese sulphate	L.R.		
58. Marble chips	L.R.		

\* L. R. = Laboratory reagent  
A. R. = Analytical reagent



Sl. No.	Organic Chemicals	Grade
1.	Acetaldehyde	L.R.
2.	Acetanilide	L.R.
3.	Acetic acid (ethanoic acid)	L.R.
4.	Acetic anhydride	L.R.
5.	Acetone	L.R.
6.	Acetyl chloride	L.R.
7.	Amyl alcohol	L.R.
8.	Aniline	L.R.
9.	Benedict's reagent	L.R.
10.	Benzene	L.R.
11.	Benzoic acid	L.R.
12.	Benzyl alcohol	L.R.
13.	Benzaldehyde	L.R.
14.	Butanol	L.R.
15.	Carbon disulphide	L.R.
16.	Carbon tetrachloride	L.R.
17.	Castor oil	L.R.
18.	Chloroform	L.R.
19.	Citric acid	L.R.
20.	Congo red (direct azo dye)	L.R.
21.	Diazoaminobenzene	L.R.
22.	<i>p</i> -dichlorobenzene	L.R.
23.	Diethyl ether	L.R.
24.	Dimethyl glyoxime	L.R.
25.	2, 4-Dinitro phenyl hydrazine	L.R.
26.	Diphenylamine	L.R.
27.	Eriochrom Black-T	AR.
28.	Ethyl acetate	L.R.
29.	Ethyl alcohol	L.R.
30.	Ethylamine	L.R.
31.	Ethylene diamine tetraacetic acid disodium salt	A.R.
32.	Fehling's solutions (A & B)	L.R.
33.	Formaldehyde	L.R.

Sl. No.	Organic Chemicals	Grade
34.	Formic acid	L.R.
35.	Fructose	L.R.
36.	Glucose	L.R.
37.	Glycerol	L.R.
38.	Lactose	L.R.
39.	Linseed oil	L.R.
40.	Liquid paraffin	L.R.
41.	Malachite green (basic dye)	L.R.
42.	Maltose	L.R.
43.	Machine oil	L.R.
44.	Methyl alcohol	L.R.
45.	Methyl orange (acidic dye)	L.R.
46.	Mustard oil	L.R.
47.	Naphthalene	L.R.
48.	1-Naphthylamine	L.R.
49.	1-Naphthol	L.R.
50.	2-Naphthol	L.R.
51.	Ninhydrin	L.R.
52.	Oxalic acid	L.R.
53.	Petroleum ether (60–80°)	L.R.
54.	Phenol	L.R.
55.	Phenolphthalein	L.R.
56.	Phenyl hydrazine hydrochloride	L.R.
57.	Phthalic acid	L.R.
58.	Phthalic anhydride	L.R.
59.	Pyridine	L.R.
60.	Pyrogallol	L.R.
61.	Resorcinol	L.R.
62.	Salicylic acid	L.R.
63.	Succinic acid	L.R.
64.	Sucrose	L.R.
65.	Thiourea	L.R.
66.	<i>p</i> -Toluidine	L.R.
67.	Urea	L.R.

Sl. No.	Glassware (Borosilicate glass)
1.	Beaker (50 mL)
2.	Beaker (100 mL)
3.	Beaker (150 mL)
4.	Beaker (250 mL)
5.	Beaker (500 mL)
6.	Boiling tubes
7.	Burette (50 mL)
8.	Conical flask (100 mL)
9.	Conical flask (150 mL)
10.	Conical flask (250 mL)
11.	Flat bottomed flask (1 litre)
12.	Funnel (8 cm diameter)
13.	Glass droppers
14.	Kipp's apparatus (diameter 1000 mm)
15.	Kjeldal's flask
16.	Liebig's condenser

Sl. No.	Glassware (Borosilicate glass)
17.	Measuring cylinder (10 mL)
18.	Measuring cylinder (50 mL)
19.	Measuring cylinder (100 mL)
20.	Measuring flask (100 mL)
21.	Measuring flask (250 mL)
22.	Petri dish (8 cm diameter)
23.	Pipette (10 mL)
24.	Pipette (25 mL)
25.	Round bottom flask (500 mL)
26.	Round bottom flask (1 litre)
27.	Separating funnel (250 mL)
28.	Test tube (15 mL)
29.	Thiele's tube
30.	Watch glass (9 cm diameter)
31.	Water aspirator weighing bottle

### Miscellaneous Articles

Sl. No. Item Description	Sl. No. Item Description
1. Agar agar	34. Polythene wash bottle (500 mL)
2. Ammeter (0-1 amp)	35. Porcelain dish
3. Beehive shelf	36. Reagent bottle (150 mL)
4. Blow pipe	37. Reagent bottle (250 mL)
5. Blue glass	38. Reagent bottle (500 mL)
6. Bunsen burner	39. Reagent bottle (2500 mL)
7. Burette brush	40. Ring clamp
8. Burette stand (wooden)	41. Rubber cork-all sizes
9. Calorimeter	42. Rubber tubing
10. Capillary tube	43. Sand paper
11. Charcoal black	44. Sand bath
12. Chemical balance	45. Spatula (plastic)
13. Clamp	46. Spirit
14. Connecting wires	47. Spirit lamp
15. Copper plate	48. Stop watch
16. Cork	49. Test tube brush
17. Cork borer sets	50. Test tube holder
18. Cork opener	51. Test tube stand (plastic)
19. Dry cell (1.5 volts)	52. Thermometer - ordinary (100°C and 360°C)
20. Filter paper sheets (Whatman and ordinary)	53. Thermometer (0-110°C and 1/10th division)
21. Fractional weights	54. Thistle funnel
22. Funnel stand	55. Triangular file
23. Gas jar with lid	56. Tripod stand (iron)
24. Glass rod	57. Trough
25. Glass tube	58. Wash bottle
26. Glass wool	59. Water bath
27. Glazed tile (white)	60. Water distillation plant
28. Ignition tube	61. Wax (paraffin)
29. Iron stand	62. Weight box (for chemical balance)
30. Key (one way)	63. Wire gauze (asbestos centre)
31. Mortar and pestle	64. Woulf bottle
32. Pair of tongs	65. Zinc plate
33. Platinum wire	

### APPENDIX III

#### PREPARATION OF COMMON LABORATORY REAGENTS

##### I. Concentration acids

	Name	Approximate concentration	Specific gravity	Approximate amount	Percentage by weight
1.	Acetic acid (glacial)	17.6 M (17.6 N)	1.06	1.06 g/mL	99.5%
2.	Conc. Hydrochloric acid	11.7 M (11.7 N)	1.19	0.426 g/mL	36.0%
3.	Conc. Nitric acid	15.6 M (15.6 N)	1.42	0.998 g/mL	69.5%
4.	Conc. Sulphuric acid	18 M (36.0 N)	1.84	1.76 g/mL	98.0%

**Note :** Concentrated acids are used as supplied.

##### II. Dilute acids

	Name	Concentration	Method of preparation
1.	Dil. Acetic acid	5 M (5 N)	Dilute 285 mL of glacial acetic acid with distilled water and make up the volume to 1 litre.
2.	Dil. Hydrochloric acid	5 M (5 N)	Add 430 mL of conc. HCl in the distilled water and make up the volume to 1 litre.
3.	Dil. Nitric acid	5 M (5 N)	Add 320 mL of conc. nitric acid to distilled water and make up the volume to litre.
4.	Dil. Sulphuric acid	2.5 M (5 N)	Pour 140 mL of conc. sulphuric acid slowly and with constant stirring in 500 mL of distilled water. Cool and make up the volume to 1 litre.

##### III. Bases

	Name	Concentration	Method of preparation
1.	Ammonia solution (Liquor ammonia)	15 M (15 N)	As supplied
2.	Dil. Ammonia solution (ammonium hydroxide)	2 M (2 N)	Pour 266.6 mL of the conc. ammonia solution in distilled water and make up the volume to 1 litre.
3.	Sodium hydroxide	5 M (5 N)	Dissolve 200 g sodium hydroxide pellets in 1 L of distilled water.

##### IV. Other reagents

	Name	Concentration	Molar mass	Method of preparation
1.	Ammonium acetate	2 M (2 N)	77	Dissolve 154 g of the salt in distilled water and dilute to 1 litre.
2.	Ammonium chloride	5 M (5 N)	53.5	Dissolve 267.5 g of the salt in distilled water and dilute to one litre.
3.	Ammonium carbonate	1.7 M (3.5 N)	96	Dissolve 160 g of ammonium carbonate in 140 mL liquor ammonia and make up the solution to 1 litre with distilled water.

4. Ammonium molybdate	-	-	Dissolve 100 g of the salt in a mixture of 100 mL of liquor ammonia solution and add 250 g of ammonium nitrate and dilute it to 1 litre with distilled water.
5. Ammonium oxalate	0.5 M (1 N)	142	Dissolve 71 g of the salt in distilled water and dilute to 1 litre.
6. Ammonia sulphate	1 M (2 N)	132	Dissolve 132 g of the salt in distilled water and dilute to 1 litre.
7. Barium chloride $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$	0.5 M (0.5 N)	244	Dissolve 61 g of the salt in distilled water and dilute to 1 litre.
8. Bromine water	approx. saturated	160	Add 2 mL of bromine in 100 mL of distilled water shake the mixture well. Keep it in a dark bottle.
9. Calcium chloride	0.5 M (0.5 N)	219	Dissolve 55 g of the salt in distilled water and make up the volume to 1 litre.
10. Chlorine water	-	71	Prepare chlorine gas by treating solid $\text{KMnO}_4$ with conc. $\text{HCl}$ . Saturate one litre of distilled water with chlorine gas and keep the solution in a dark coloured bottle.
11. Copper sulphate	14%	249.5	Dissolve 14 g of the salt in distilled water and make up the volume to 100 mL.
12. Cobalt nitrate	0.15 M (0.075 N)	291	Dissolve 43.65 g of the salt in distilled water and make up the volume to 1 litre.
13. Dimethyl glyoxime	1%		Dissolve 1.0 g of the solid in 100 mL ethyl alcohol.
14. Diphenylamine	0.5%		Dissolve 0.5 g of the solid in 85 mL of conc. sulphuric acid and dilute it with care with distilled water to 100 mL.
15. Disodium hydrogen phosphate $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$	0.3 M (N)	358	Dissolve 120.0 g of the salt in distilled water and make up the volume to litre.
16. Ferric chloride $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$	0.33 M (1 N)	270	Dissolve 90 g of the salt in distilled water containing 10 mL of conc. hydrochloric acid and make up the volume to 1 litre.
17. Iodine solution		254	Dissolve 1.0 g of iodine crystals in a solution of 2 g potassium iodide in minimum amount of water and dilute the solution to 100 mL.
18. Lead acetate $(\text{CH}_3\text{COO})_2\text{Pb}$	0.5 M (N)		Dissolve 200 g of solid salt in 500 mL of distilled water containing 15 mL acetic acid and make up the volume to 1 litre with distilled water.
19. Lime water $\text{Ca}(\text{OH})_2$	0.02 M (0.04 N)	74	Shake 2–3 g of calcium hydroxide with 1 L distilled water, filter the solution after some time and keep it in a reagent bottle. Bottle should be securely stoppered in order to protect the reagent from $\text{CO}_2$ of atmosphere.
20. Litmus solution (blue)	-		Dissolve 10 g of litmus in distilled water and make the volume to 1 litre.
21. Litmus solution (red)	-		To the blue litmus solution add about 10 drops of dilute hydrochloric acid.
22. Methyl orange			Dissolve 1 g of the solid in 1 litre of distilled water.
23. Mercuric chloride	0.25 M (0.5 N)	272	Dissolve 70 g of the salt in small amount of distilled water and make up the volume to 1 litre with distilled water.

24. Nessler's reagent	-		Dissolve 23 g of mercuric iodide and 16 g of potassium iodide in distilled water and make up the volume to 100 mL. Add 150 mL of 4 M NaOH solution. Allow it to stand for 24 hours and decant the solution. Solution should be stored in a dark coloured bottle.
25. Potassium chromate $K_2CrO_4$	0.25 M (0.5 N)	194	Dissolve 49 g of the salt in distilled water and make up the volume to 1 litre.
26. Potassium dichromate	0.15 M (1 N)	294	Dissolve 49.0 g of the salt in distilled water and make up the volume to 1 litre.
27. Potassium ferrocyanide	0.15 M (0.5 N)	368	Dissolve 46.0 g of the salt in distilled water and dilute to 1 litre.
28. Potassium ferricyanide	0.2 M (0.5 N)	329	Dissolve 55.0 g of the salt in distilled water and dilute to 1 litre.
29. Potassium iodide	0.5 M (0.5 N)	166	Dissolve 83.0 g of the salt in distilled water and make up the volume to 1 litre.
30. Potassium permanganate	0.06 M (0.3 N)	158	Dissolve 10.0 g of the salt in 1 litre distilled water. Heat the solution and filter it through glass wool.
31. Potassium thiocyanate	0.5 M (0.5 N)	97	Dissolve 49.0 g of the salt in distilled water and make up the volume to 1 litre.
32. Phenolphthalein	1%		Dissolve 1.0 g of the solid in 100 mL of ethyl alcohol.
33. Silver nitrate	0.1 M	170	Dissolve 17 g of the salt in 250 mL of distilled water and store it in a brown coloured bottle.
34. Sodium acetate	5 M (5 N)	82	Dissolve 410 g of salt in distilled water and dilute to 1 litre.
35. Sodium nitroprusside			Dissolve 4 g of the solid in 100 mL of distilled water.
36. Starch			Prepare a paste of about 1.0 g of soluble starch in cold water and pour it gradually in 100 mL of boiling water with constant stirring. Boil it for 10 minutes and cool.
37. Stannous chloride $SnCl_2 \cdot 2H_2O$	0.25 M (0.5 N)	226	Dissolve 55.0 g of the salt in 200 mL of conc. hydrochloric acid by heating (if necessary). Dilute with distilled water to make up the volume to 1 litre. Add several pieces of metallic tin into the solution.
38. Yellow ammonium sulphide $(NH_4)_2S_x$	6 N		Take about 200 mL of conc. ammonia solution in a bottle and saturate it with $H_2S$ gas. Add 10 g of flower of sulphur and 200 mL of conc. $NH_4OH$ . Warm gently and shake well until sulphur is completely dissolved. Dilute the solution to 1 litre with distilled water.
39. Buffer solution in non-aqueous media (For EDTA titration)			Dissolved 67.5 g of ammonium chloride in 570 mL conc. ammonia solution and make up the volume to 1 L.
40. Eriochrome Black T in non aqueous media (Indicator for EDTA titration)			Dissolve 0.5 gram of solid Eriochrome Black-T in methanol and make up the volume to 100 mL.

### Special Reagents Used in Organic Analysis

1. Alcohol (1:1)	: Mix equal volumes of rectified spirit and distilled water.
2. Alcoholic potassium hydroxide solution	: Dissolve 11.2 g of potassium hydroxide in 100 mL ethand (or rectified spirit) by boiling for 30 minutes.
3. Alkaline $\beta$ -naphthol	: Dissolve 10 g of $\beta$ -naphthol in 100 mL of 10% sodium hydroxide solution.
4. Barfoed reagent	: Dissolve 13 g of copper acetate in 200 mL of 1% acetic acid.
5. Benedict's solution	: Dissolve 17.3 g of crystalline copper sulphate in 100 mL of water. Separately dissolve 173 g of sodium citrate and 100 g of anhydrous sodium carbonate in 800 mL of water. Mix both solutions and make up the volume to 1 L.
6. Ceric ammonium nitrate solution	: Dissolve 40 g of the reagent in 100 mL of 2 N nitric acid.
7. Copper sulphate solution	: Dissolve 14 g of copper sulphate in 100 mL water (14% solution)
8. 2,4-dinitrophenylhydrazine reagent	:
(i) For water soluble compounds	: Add 0.5 g solid in a mixture of 42 mL conc. HCl and 54 mL water and dissolve by warming on water bath. Add water to make up the volume to 250 mL.
(ii) For compounds not soluble in water	: Dissolve 1 g of reagent in 7.5 mL conc. sulphuric acid. Add this solution gradually to 7.5 mL rectified spirit. Make up the volume to 250 mL by adding water.
9. *Fehling's solution A	: Dissolve 69.28 g of copper sulphate crystals in 1 L of water.
10. *Fehling's solution B	: Dissolve 350 g of Rochelle's salt and 100 g sodium hydroxide in 1 L water.
11. Hydroxylamine hydrochloride	: Dissolve 69.5 g of dry solid in 1 L of methyl alcohol.
12. Molisch's reagent	: Dissolve 10 g of 1-naphthol in 90 mL of rectified spirit.
13. Ninhydrin reagent	: Prepare 0.25% aqueous solution.
14. Potassium permanganate	: Prepare 1 % aqueous solution.
15. Schiff's reagent	: Dissolve 1 g of rosaniline in 50 mL water with gentle warming, cool, saturate with sulphur dioxide gas. Dilute the solution upto 1 L with water. If pink colour reappears on standing add few drops of saturated aqueous solution of SO <sub>2</sub> with stirring until the colour just disappears.
16. Seliwanoff's reagent	: Dissolve 1 g of resorcinol in 100 mL of 20% hydrochloric acid.
17. Sodium hypochlorite (2M)	: Dissolve 100 g of NaOH in 200 mL of water in a large beaker. Cool the solution and add about 500 g of crushed ice. Weigh the beaker on a rough balance and pass chlorine gas until the weight increases by 72 g. Dilute the solution to 1 L with water. The solution must be kept in a cool dark place. Even then it slowly decomposes.
18. Tollen's reagent	: To 1 mL of 2% solution of silver nitrate add 1 mL of 10% sodium hydroxide till the precipitate just appears. Add solution of ammonium hydroxide with stirring till the solution becomes clear. Ammonium hydroxide should not be added in excess. Always use fresh Tollen's reagent.

\*Before use, mix equal volumes of Fehling's solution A and Fehling's solution B.

## APPENDIX IV

### SOME USEFUL TABLES

**Table 1 : Fundamental physical constants**

Physical constant	Symbol	Value
Acceleration due to gravity	$g$	$9.81 \text{ ms}^{-2}$
Atomic mass unit	$\text{amu}$	$1.66053 \times 10^{-27} \text{ Kg}$
Avogadro constant	$N_A$	$6.02217 \times 10^{23} \text{ mol}^{-1}$
Boltzmann constant	$K$	$1.38062 \times 10^{-23} \text{ J K}^{-1}$
Electronic charge	$e$	$1.602192 \times 10^{-19} \text{ C}$
Faraday constant	$F$	$9.64867 \times 10^4 \text{ C mol}^{-1}$
Gas constant	$R$	$8.314 \text{ J K}^{-1} \text{ mol}^{-1}$
'Ice-point' temperature	$T_{ice}$	$273.150 \text{ K}$
Molar volume of ideal gas at stp.	$V_m$	$2.24136 \times 10^{-2} \text{ m}^3 \text{ mol}^{-1}$
Permittivity of a vacuum	$\epsilon_0$	$8.854185 \times 10^{-12} \text{ Kg}^{-1} \text{ m}^{-3} \text{ s}^4 \text{ A}^2$
Plank constant	$h$	$6.62620 \times 10^{-34} \text{ J s}$
Rydberg constant	$R_w$	$1.973731 \times 10^7 \text{ m}^{-1}$
Standard pressure (atmosphere)	$p$	$101325 \text{ N m}^{-2}$
Triple point of water		$273.016 \text{ K}$
Velocity of light of vacuum	$c$	$2.997925 \times 10^8 \text{ m s}^{-1}$

**Table 2 : General properties of some organic compounds**

Compound	mp.°C	bp.°C	Density/ Kg m <sup>-3</sup> (298 K)	Refractive index (nD) (293 K)	10 <sup>4</sup> × Viscosity/ N s m <sup>-2</sup> (298 K)	10 <sup>3</sup> × Surface Tension/ N m <sup>-1</sup> (293 K)
Acetic acid	16.7	117.9	1044.0	1.3716	11.55	27.8
Acetone	-94.7	56.1	785.0	1.3588	3.16	23.7
Aniline	-6.3	184.1	1022.0 (293)	1.5863	3.71	42.9
Benzoic acid	122.4	249.0	1266.0 (288)	1.504 (405)	-	-
Carbon tetra-chloride	-22.9	76.5	1584.0	1.4601	8.8	26.95
Chlorobenzene	-45.2	132.0	1106.0	1.5241	7.97	33.56
Chloroform	-63.5	61.7	1480.0	1.4459	5.42	27.14
Cyclohexane	6.6	80.7	774.0	1.42662	9.8	25.5
Di-ethyl ether	-116.2	34.51	714.0	1.3526	2.22	17.01
Ethyl acetate	-82.4	77.1	900.0 (293)	1.3723	4.41	23.9
Ethanol	-114.1	78.3	785.0	1.3611	10.6	22.75
Glycerol	18.07	290.0	1264.4	1.4746	942.0	63.4
Hexane	-95.3	68.7	655.0	1.37506	2.94	18.43
Methanol	-97.7	64.5	787.0	1.3288	5.47	22.61
Napthalene	80.3	218.0	1180.0	1.4003 (297)	-	-
Phenol	40.9	181.8	1132.0	1.5509	-	-
Toluene	-95.1	110.6	862.0	1.4961	5.50	28.5



**Table 3 : Solubility of common inorganic compounds in water**

Name of Anion	Symbol	These ions form soluble compounds (solubility greater than 0.1 M) with these cations	Form slightly soluble compounds (solubility less than 0.1 M)
nitrate	$\text{NO}_3^-$	Most cations	None
acetate	$\text{CH}_3\text{COO}^-$	Most cations	$\text{Ag}^+$
chloride	$\text{Cl}^-$	Most cations	$\text{Ag}^+$ , $\text{Pb}^{2+}$ , $\text{Hg}_2^{2+}$
bromide	$\text{Br}^-$	Most cations	$\text{Ag}^+$ , $\text{Pb}^{2+}$ , $\text{Hg}_2^{2+}$
iodide	$\text{I}^-$	Most cations	$\text{Ag}^+$ , $\text{Pb}^{2+}$ , $\text{Hg}_2^{2+}$
sulphate	$\text{SO}_4^{2-}$	Most cations	$\text{Ba}^{2+}$ , $\text{Sr}^{2+}$ , $\text{Pb}^{2+}$ , $\text{Ag}^+$
chromate	$\text{CrO}_4^{2-}$	Most cations	$\text{Ba}^{2+}$ , $\text{Sr}^{2+}$ , $\text{Pb}^{2+}$ , $\text{Ag}^+$
sulphide	$\text{S}^{2-}$	$\text{NH}_4^+$ , alkali metal cations, and alkaline earth metal cations	Most other cations
hydroxide	$\text{OH}^-$	$\text{NH}_4^+$ , alkali metal and alkaline earth metal and $\text{Ba}^{2+}$ and $\text{Sr}^{2+}$	Most other cations
carbonate	$\text{CO}_3^{2-}$	$\text{NH}_4^+$ and alkali metal cations	Most other cations
phosphate	$\text{PO}_4^{3-}$	except $\text{Li}^+$	

## APPENDIX V

### ELEMENTS, THEIR ATOMIC NUMBER AND MOLAR MASS

Element	Symbol	Atomic Number	Molar mass/ (g mol <sup>-1</sup> )
Actinium	Ac	89	227.03
Aluminium	Al	13	26.98
Americium	Am	95	(243)
Antimony	Sb	51	121.75
Argon	Ar	18	39.95
Arsenic	As	33	74.92
Astatine	At	85	210
Barium	Ba	56	137.34
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.01
Bismuth	Bi	83	208.98
Bohrium	Bh	107	(264)
Boron	B	5	10.81
Bromine	Br	35	79.91
Cadmium	Cd	48	112.40
Caesium	Cs	55	132.91
Calcium	Ca	20	40.08
Californium	Cf	98	251.08
Carbon	C	6	12.01
Cerium	Ce	58	140.12
Chlorine	Cl	17	35.45
Chromium	Cr	24	52.00
Cobalt	Co	27	58.93
Copper	Cu	29	63.54
Curium	Cm	96	247.07
Dubnium	Db	105	(263)
Dysprosium	Dy	66	162.50
Einsteinium	Es	99	(252)
Erbium	Er	68	167.26
Europium	Eu	63	151.96
Fermium	Fm	100	(257.10)
Fluorine	F	9	19.00
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.72
Germanium	Ge	32	72.61
Gold	Au	79	196.97
Hafnium	Hf	72	178.49
Hassium	Hs	108	(269)
Helium	He	2	4.00
Holmium	Ho	67	164.93
Hydrogen	H	1	1.0079
Indium	In	49	114.82
Iodine	I	53	126.90
Iridium	Ir	77	192.2
Iron	Fe	26	55.85
Krypton	Kr	36	83.80
Lanthanum	La	57	138.91
Lawrencium	Lr	103	(262.1)
Lead	Pb	82	207.19
Lithium	Li	3	6.94
Lutetium	Lu	71	174.96
Magnesium	Mg	12	24.31
Manganese	Mn	25	54.94
Meitneium	Mt	109	(268)
Mendelevium	Md	101	258.10

Element	Symbol	Atomic Number	Molar mass/ (g mol <sup>-1</sup> )
Mercury	Hg	80	200.59
Molybdenum	Mo	42	95.94
Neodymium	Nd	60	144.24
Neon	Ne	10	20.18
Neptunium	Np	93	(237.05)
Nickel	Ni	28	58.71
Niobium	Nb	41	92.91
Nitrogen	N	7	14.0067
Nobelium	No	102	(259)
Osmium	Os	76	190.2
Oxygen	O	8	16.00
Palladium	Pd	46	106.4
Phosphorus	P	15	30.97
Platinum	Pt	78	195.09
Plutonium	Pu	94	(244)
Polonium	Po	84	210
Potassium	K	19	39.10
Praseodymium	Pr	59	140.91
Promethium	Pm	61	(145)
Protactinium	Pa	91	231.04
Radium	Ra	88	(226)
Radon	Rn	86	(222)
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.91
Rubidium	Rb	37	85.47
Ruthenium	Ru	44	101.07
Rutherfordium	Rf	104	(261)
Samarium	Sm	62	150.35
Scandium	Sc	21	44.96
Seaborgium	Sg	106	(266)
Selenium	Se	34	78.96
Silicon	Si	14	28.08
Silver	Ag	47	107.87
Sodium	Na	11	22.99
Strontium	Sr	38	87.62
Sulphur	S	16	32.06
Tantalum	Ta	73	180.95
Technetium	Tc	43	(98.91)
Tellurium	Te	52	127.60
Terbium	Tb	65	158.92
Thallium	Tl	81	204.37
Thorium	Th	90	232.04
Thulium	Tm	69	168.93
Tin	Sn	50	118.69
Titanium	Ti	22	47.88
Tungsten	W	74	183.85
Ununbium	Uub	112	(277)
Ununnilium	Uun	110	(269)
Unununium	Uuu	111	(272)
Uranium	U	92	238.03
Vanadium	V	23	50.94
Xenon	Xe	54	131.30
Ytterbium	Yb	70	173.04
Yttrium	Y	39	88.91
Zinc	Zn	30	65.37
Zirconium	Zr	40	91.22

The value given in parenthesis is the molar mass of the isotope of largest known half-life.

## APPENDIX VI

### SOME USEFUL CONVERSION FACTORS

#### Common Unit of Mass and Weight

**1 pound = 453.59 grams**

1 pound = 453.59 grams = 0.45359 kilogram

1 kilogram = 1000 grams = 2.205 pounds

1 gram = 10 decigrams = 100 centigrams  
= 1000 milligrams

1 gram =  $6.022 \times 10^{23}$  atomic mass units or u

1 atomic mass unit =  $1.6606 \times 10^{-24}$  gram

1 metric tonne = 1000 kilograms  
= 2205 pounds

#### Common Unit of Volume

**1 quart = 0.9463 litre**

**1 litre = 1.056 quarts**

1 litre = 1 cubic decimetre = 1000 cubic  
centimetres = 0.001 cubic metre

1 millilitre = 1 cubic centimetre = 0.001 litre  
=  $1.056 \times 10^{-3}$  quart

1 cubic foot = 28.316 litres = 29.902 quarts  
= 7.475 gallons

#### Common Units of Energy

**1 joule =  $1 \times 10^7$  ergs**

1 thermochemical calorie\*\* = 4.184 joules  
=  $4.184 \times 10^7$  ergs  
=  $4.129 \times 10^{-2}$  litre-atmospheres  
=  $2.612 \times 10^{19}$  electron volts

1 ergs =  $1 \times 10^{-7}$  joule =  $2.3901 \times 10^{-8}$  calorie

1 electron volt =  $1.6022 \times 10^{-19}$  joule  
=  $1.6022 \times 10^{-12}$  erg  
= 96.487 kJ/mol†

1 litre-atmosphere = 24.217 calories  
= 101.32 joules  
=  $1.0132 \times 10^9$  ergs

1 British thermal unit = 1055.06 joules  
=  $1.05506 \times 10^{10}$  ergs  
= 252.2 calories

#### Common Units of Length

**1 inch = 2.54 centimetres (exactly)**

1 mile = 5280 feet = 1.609 kilometres

1 yard = 36 inches = 0.9144 metre

1 metre = 100 centimetres  
= 39.37 inches  
= 3.281 feet  
= 1.094 yards

1 kilometre = 1000 metres  
= 1094 yards  
= 0.6215 mile

1 Angstrom =  $1.0 \times 10^{-8}$  centimetre  
= 0.10 nanometre  
=  $1.0 \times 10^{-10}$  metre  
=  $3.937 \times 10^{-9}$  inch

#### Common Units of Force\* and Pressure

1 atmosphere = 760 millimetres of mercury  
=  $1.013 \times 10^5$  pascals  
= 14.70 pounds per square inch

1 bar =  $10^5$  pascals

1 torr = 1 millimetre of mercury

1 pascal =  $1 \text{ kg/ms}^2 = 1 \text{ N/m}^2$

#### Temperature

**SI Base Unit: Kelvin (K)**

K =  $-273.15^\circ\text{C}$

K =  $^\circ\text{C} + 273.15$

$^\circ\text{F} = 1.8(^\circ\text{C}) + 32$

$^\circ\text{C} = \frac{^\circ\text{F} - 32}{1.8}$

\* Force: 1 newton (N) =  $1 \text{ kg m/s}^2$ , i.e., the force that, when applied for 1 second, gives a 1-kilogram mass a velocity of 1 metre per second.

\*\* The amount of heat required to raise the temperature of one gram of water from  $14.5^\circ\text{C}$  to  $15.5^\circ\text{C}$ .

† Note that the other units are per particle and must be multiplied by  $6.022 \times 10^{23}$  to be strictly comparable.

# APPENDIX VII

## STANDARD POTENTIALS AT 298 K IN ELECTROCHEMICAL

Reduction half-reaction	$E^\circ / V$	Reduction half-reaction	$E^\circ / V$
$H_4XeO_6 + 2H^+ + 2e^- \longrightarrow XeO_3 + 3H_2O$	+3.0	$Pu^{4+} + e^- \longrightarrow Pu^{3+}$	+0.97
$F_2 + 2e^- \longrightarrow 2F^-$	+2.87	$NO_3^- + 4H^+ + 3e^- \longrightarrow NO + 2H_2O$	+0.96
$O_3 + 2H^+ + 2e^- \longrightarrow O_2 + H_2O$	+2.07	$2Hg^{2+} + 2e^- \longrightarrow Hg_2^{2+}$	+0.92
$S_2O_8^{2-} + 2e^- \longrightarrow 2SO_4^{2-}$	+2.05	$ClO^- + H_2O + 2e^- \longrightarrow Cl^- + 2OH^-$	+0.89
$Ag^+ + e^- \longrightarrow Ag$	+1.98	$Hg^{2+} + 2e^- \longrightarrow Hg$	+0.86
$Co^{3+} + e^- \longrightarrow Co^{2+}$	+1.81	$NO_3^- + 2H^+ + e^- \longrightarrow NO_2 + H_2O$	+0.80
$H_2O_2 + 2H^+ + 2e^- \longrightarrow 2H_2O$	+1.78	$Ag^+ + e^- \longrightarrow Ag$	+0.80
$Au^+ + e^- \longrightarrow Au$	+1.69	$Hg_2^{2+} + 2e^- \longrightarrow 2Hg$	+0.79
$Pb^{4+} + 2e^- \longrightarrow Pb^{2+}$	+1.67	$Fe^{3+} + e^- \longrightarrow Fe^{2+}$	+0.77
$2HClO + 2H^+ + 2e^- \longrightarrow Cl_2 + 2H_2O$	+1.63	$BrO^- + H_2O + 2e^- \longrightarrow Br^- + 2OH^-$	+0.76
$Ce^{4+} + e^- \longrightarrow Ce^{3+}$	+1.61	$Hg_2SO_4 + 2e^- \longrightarrow 2Hg + SO_4^{2-}$	+0.62
$2HBrO + 2H^+ + 2e^- \longrightarrow Br_2 + 2H_2O$	+1.60	$MnO_4^{2-} + 2H_2O + 2e^- \longrightarrow MnO_2 + 4OH^-$	+0.60
$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$	+1.51	$MnO_4^- + e^- \longrightarrow MnO_4^{2-}$	+0.56
$Mn^{3+} + e^- \longrightarrow Mn^{2+}$	+1.51	$I_2 + 2e^- \longrightarrow 2I^-$	+0.54
$Au^{3+} + 3e^- \longrightarrow Au$	+1.40	$I_3^- + 2e^- \longrightarrow 3I^-$	+0.53
$Cl_2 + 2e^- \longrightarrow 2Cl^-$	+1.36	$Cu^+ + e^- \longrightarrow Cu$	+0.52
$Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$	+1.33	$NiOOH + H_2O + e^- \longrightarrow Ni(OH)_2 + OH^-$	+0.49
$O_3 + H_2O + 2e^- \longrightarrow O_2 + 2OH^-$	+1.24	$Ag_2CrO_4 + 2e^- \longrightarrow 2Ag + CrO_4^{2-}$	+0.45
$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$	+1.23	$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$	+0.40
$ClO_4^- + 2H^+ + 2e^- \longrightarrow ClO_3^- + H_2O$	+1.23	$ClO_4^- + H_2O + 2e^- \longrightarrow ClO_3^- + 2OH^-$	+0.36
$MnO_2 + 4H^+ + 2e^- \longrightarrow Mn^{2+} + 2H_2O$	+1.23	$[Fe(CN)_6]^{3-} + e^- \longrightarrow [Fe(CN)_6]^{4-}$	+0.36
$Pt^{2+} + 2e^- \longrightarrow Pt$	+1.20	$Cu^{2+} + 2e^- \longrightarrow Cu$	+0.34
$Br_2 + 2e^- \longrightarrow 2Br^-$	+1.09	$Hg_2Cl_2 + 2e^- \longrightarrow 2Hg + 2Cl^-$	+0.27

$\text{AgCl} + \text{e}^- \longrightarrow \text{Ag} + \text{Cl}^-$	+0.27	$\text{S} + 2\text{e}^- \longrightarrow \text{S}^{2-}$	-0.48
$\text{Bi}^{3+} + 3\text{e}^- \longrightarrow \text{Bi}$	+0.20	$\text{In}^{3+} + \text{e}^- \longrightarrow \text{In}^{2+}$	-0.49
$\text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e}^- \longrightarrow \text{H}_2\text{SO}_3 + \text{H}_2\text{O}$	+0.17	$\text{U}^{4+} + \text{e}^- \longrightarrow \text{U}^{3+}$	-0.61
$\text{Cu}^{2+} + \text{e}^- \longrightarrow \text{Cu}^+$	+0.16	$\text{Cr}^{3+} + 3\text{e}^- \longrightarrow \text{Cr}$	-0.74
$\text{Sn}^{4+} + 2\text{e}^- \longrightarrow \text{Sn}^{2+}$	+0.15	$\text{Zn}^{2+} + 2\text{e}^- \longrightarrow \text{Zn}$	-0.76
$\text{AgBr} + \text{e}^- \longrightarrow \text{Ag} + \text{Br}^-$	+0.07	$\text{Cd}(\text{OH})_2 + 2\text{e}^- \longrightarrow \text{Cd} + 2\text{OH}^-$	-0.81
$\text{Ti}^{4+} + \text{e}^- \longrightarrow \text{Ti}^{3+}$	0.00	$2\text{H}_2\text{O} + 2\text{e}^- \longrightarrow \text{H}_2 + 2\text{OH}^-$	-0.83
$2\text{H}^+ + 2\text{e}^- \longrightarrow \text{H}_2$ (by definition)	0.0	$\text{Cr}^{2+} + 2\text{e}^- \longrightarrow \text{Cr}$	-0.91
$\text{Fe}^{3+} + 3\text{e}^- \longrightarrow \text{Fe}$	-0.04	$\text{Mn}^{2+} + 2\text{e}^- \longrightarrow \text{Mn}$	-1.18
$\text{O}_2 + \text{H}_2\text{O} + 2\text{e}^- \longrightarrow \text{HO}_2^- + \text{OH}^-$	-0.08	$\text{V}^{2+} + 2\text{e}^- \longrightarrow \text{V}$	-1.19
$\text{Pb}^{2+} + 2\text{e}^- \longrightarrow \text{Pb}$	-0.13	$\text{Ti}^{2+} + 2\text{e}^- \longrightarrow \text{Ti}$	-1.63
$\text{In}^+ + \text{e}^- \longrightarrow \text{In}$	-0.14	$\text{Al}^{3+} + 3\text{e}^- \longrightarrow \text{Al}$	-1.66
$\text{Sn}^{2+} + 2\text{e}^- \longrightarrow \text{Sn}$	-0.14	$\text{U}^{3+} + 3\text{e}^- \longrightarrow \text{U}$	-1.79
$\text{AgI} + \text{e}^- \longrightarrow \text{Ag} + \text{I}^-$	-0.15	$\text{Sc}^{3+} + 3\text{e}^- \longrightarrow \text{Sc}$	-2.09
$\text{Ni}^{2+} + 2\text{e}^- \longrightarrow \text{Ni}$	-0.23	$\text{Mg}^{2+} + 2\text{e}^- \longrightarrow \text{Mg}$	-2.36
$\text{V}^{3+} + \text{e}^- \longrightarrow \text{V}^{2+}$	-0.26	$\text{Ce}^{3+} + 3\text{e}^- \longrightarrow \text{Ce}$	-2.48
$\text{Co}^{2+} + 2\text{e}^- \longrightarrow \text{Co}$	-0.28	$\text{La}^{3+} + 3\text{e}^- \longrightarrow \text{La}$	-2.52
$\text{In}^{3+} + 3\text{e}^- \longrightarrow \text{In}$	-0.34	$\text{Na}^+ + \text{e}^- \longrightarrow \text{Na}$	-2.71
$\text{Tl}^+ + \text{e}^- \longrightarrow \text{Tl}$	-0.34	$\text{Ca}^{2+} + 2\text{e}^- \longrightarrow \text{Ca}$	-2.87
$\text{PbSO}_4 + 2\text{e}^- \longrightarrow \text{Pb} + \text{SO}_4^{2-}$	-0.36	$\text{Sr}^{2+} + 2\text{e}^- \longrightarrow \text{Sr}$	-2.89
$\text{Ti}^{3+} + \text{e}^- \longrightarrow \text{Ti}^{2+}$	-0.37	$\text{Ba}^{2+} + 2\text{e}^- \longrightarrow \text{Ba}$	-2.91
$\text{Cd}^{2+} + 2\text{e}^- \longrightarrow \text{Cd}$	-0.40	$\text{Ra}^{2+} + 2\text{e}^- \longrightarrow \text{Ra}$	-2.92
$\text{In}^{2+} + \text{e}^- \longrightarrow \text{In}^+$	-0.40	$\text{Cs}^+ + \text{e}^- \longrightarrow \text{Cs}$	-2.92
$\text{Cr}^{3+} + \text{e}^- \longrightarrow \text{Cr}^{2+}$	-0.41	$\text{Rb}^+ + \text{e}^- \longrightarrow \text{Rb}$	-2.93
$\text{Fe}^{2+} + 2\text{e}^- \longrightarrow \text{Fe}$	-0.44	$\text{K}^+ + \text{e}^- \longrightarrow \text{K}$	-2.93
$\text{In}^{3+} + 2\text{e}^- \longrightarrow \text{In}^+$	-0.44	$\text{Li}^+ + \text{e}^- \longrightarrow \text{Li}$	-3.05

## APPENDIX VIII

### LOGARITHMS

Sometimes, a numerical expression may involve multiplication, division or rational powers of large numbers. For such calculations, logarithms are very useful. They help us in making difficult calculations easy. In Chemistry, logarithm values are required in solving problems of chemical kinetics, thermodynamics, electrochemistry, etc. We shall first introduce this concept, and discuss the laws, which will have to be followed in working with logarithms, and then apply this technique to a number of problems to show how it makes difficult calculations simple.

We know that

$$2^3 = 8, 3^2 = 9, 5^3 = 125, 7^0 = 1$$

In general, for a positive real number  $a$ , and a rational number  $m$ , let  $a^m = b$ ,

where  $b$  is a real number. In other words

the  $m^{\text{th}}$  power of base  $a$  is  $b$ .

Another way of stating the same fact is

logarithm of  $b$  to base  $a$  is  $m$ .

If for a positive real number  $a$ ,  $a \neq 1$

$$a^m = b,$$

we say that  $m$  is the logarithm of  $b$  to the base  $a$ .

We write this as  $\log_a b = m$ ,

“log” being the abbreviation of the word “logarithm”.

Thus, we have

$$\log_2 8 = 3, \quad \text{Since } 2^3 = 8$$

$$\log_3 9 = 2, \quad \text{Since } 3^2 = 9$$

$$\log_5 125 = 3, \quad \text{Since } 5^3 = 125$$

$$\log_7 1 = 0, \quad \text{Since } 7^0 = 1$$

#### Laws of Logarithms

In the following discussion, we shall take logarithms to any base  $a$ , ( $a > 0$  and  $a \neq 1$ )

**First Law:**  $\log_a (mn) = \log_a m + \log_a n$

**Proof:** Suppose that  $\log_a m = x$  and  $\log_a n = y$

Then  $a^x = m$ ,  $a^y = n$

$$\text{Hence } mn = a^x \cdot a^y = a^{x+y}$$

It now follows from the definition of logarithms that

$$\log_a (mn) = x + y = \log_a m + \log_a n$$

**Second Law:**  $\log_a \left( \frac{m}{n} \right) = \log_a m - \log_a n$

**Proof:** Let  $\log_a m = x$ ,  $\log_a n = y$

Then  $a^x = m$ ,  $a^y = n$

$$\text{Hence } \frac{m}{n} = \frac{a^x}{a^y} = a^{x-y}$$

Therefore

$$\log_a \left( \frac{m}{n} \right) = x - y = \log_a m - \log_a n$$

Third Law :

$$\log_a(m^n) = n \log_a m$$

**Proof :** As before, if  $\log_a m = x$ , then  $a^x = m$

$$\text{Then } m^n = (a^x)^n = a^{nx}$$

$$\text{giving } \log_a(m^n) = nx = n \log_a m$$

Thus according to First Law: "the log of the product of two numbers is equal to the sum of their logs. Similarly, the Second Law says: the log of the ratio of two numbers is the difference of their logs. Thus, the use of these laws converts a problem of multiplication / division into a problem of addition/subtraction, which are far easier to perform than multiplication/division. That is why logarithms are so useful in all numerical computations.

### Logarithms to Base 10

Because number 10 is the base of writing numbers, it is very convenient to use logarithms to the base 10. Some examples are:

$$\begin{array}{ll} \log_{10} 10 = 1, & \text{since } 10^1 = 10 \\ \log_{10} 100 = 2, & \text{since } 10^2 = 100 \\ \log_{10} 10000 = 4, & \text{since } 10^4 = 10000 \\ \log_{10} 0.01 = -2, & \text{since } 10^{-2} = 0.01 \\ \log_{10} 0.001 = -3, & \text{since } 10^{-3} = 0.001 \\ \text{and } \log_{10} 1 = 0 & \text{since } 10^0 = 1 \end{array}$$

The above results indicate that if  $n$  is an integral power of 10, i.e., 1 followed by several zeros or 1 preceded by several zeros immediately to the right of the decimal point, then  $\log n$  can be easily found.

If  $n$  is not an integral power of 10, then it is not easy to calculate  $\log n$ . But mathematicians have made tables from which we can read off approximate value of the logarithm of any positive number between 1 and 10. And these are sufficient for us to calculate the logarithm of any number expressed in decimal form. For this purpose, we always express the given decimal as the product of an integral power of 10 and a number between 1 and 10.

### Standard Form of Decimal

We can express any number in decimal form, as the product of (i) an integral power of 10, and (ii) a number between 1 and 10. Here are some examples:

- (i) 25.2 lies between 10 and 100



$$25.2 = \frac{25.2}{10} \times 10 = 2.52 \times 10^1$$

(ii) 1038.4 lies between 1000 and 10000.

$$\therefore 1038.4 = \frac{1038.4}{1000} \times 10^3 = 1.0384 \times 10^3$$

(iii) 0.005 lies between 0.001 and 0.01

$$\therefore 0.005 = (0.005 \times 1000) \times 10^{-3} = 5.0 \times 10^{-3}$$

(iv) 0.00025 lies between 0.0001 and 0.001

$$\therefore 0.00025 = (0.00025 \times 10000) \times 10^{-4} = 2.5 \times 10^{-4}$$

In each case, we divide or multiply the decimal by a power of 10, to bring one non-zero digit to the left of the decimal point, and do the reverse operation by the same power of 10, indicated separately.

Thus, any positive decimal can be written in the form

$$n = m \times 10^p$$

where  $p$  is an integer (positive, zero or negative) and  $1 \leq m < 10$ . This is called the “standard form of  $n$ .”

### Working Rule

1. Move the decimal point to the left, or to the right, as may be necessary, to bring one non-zero digit to the left of decimal point.
2. (i) If you move  $p$  places to the left, multiply by  $10^p$ .  
 (ii) If you move  $p$  places to the right, multiply by  $10^{-p}$ .  
 (iii) If you do not move the decimal point at all, multiply by  $10^0$ .  
 (iv) Write the new decimal obtained by the power of 10 (of step 2) to obtain the standard form of the given decimal.

### Characteristic and Mantissa

Consider the standard form of  $n$

$$n = m \times 10^p, \text{ where } 1 \leq m < 10$$

Taking logarithms to the base 10 and using the laws of logarithms

$$\begin{aligned} \log n &= \log m + \log 10^p \\ &= \log m + p \log 10 \\ &= p + \log m \end{aligned}$$

Here  $p$  is an integer and as  $1 \leq m < 10$ , so  $0 \leq \log m < 1$ , i.e.,  $m$  lies between 0 and 1. When  $\log n$  has been expressed as  $p + \log m$ , where  $p$  is an integer and  $0 \leq \log m < 1$ , we say that  $p$  is the “characteristic” of  $\log n$  and that  $\log m$  is the “mantissa of  $\log n$ .” Note that characteristic is always an integer – positive, negative or zero, and mantissa is never negative and is always less than 1. If we can find the characteristics and the mantissa of  $\log n$ , we have to just add them to get  $\log n$ .

Thus to find  $\log n$ , all we have to do is as follows:

1. Put  $n$  in the standard form, say

$$n = m \times 10^p, 1 \leq m < 10$$

2. Read off the characteristic  $p$  of  $\log n$  from this expression (exponent of 10).
3. Look up  $\log m$  from tables, which is being explained below.
4. Write  $\log n = p + \log m$

If the characteristic  $p$  of a number  $n$  is say, 2 and the mantissa is .4133, then we have  $\log n = 2 + .4133$  which we can write as 2.4133. If, however, the characteristic  $p$  of a number  $m$  is say -2 and the mantissa is .4123, then we have  $\log m = -2 + .4123$ . We cannot write this as -2.4123. (Why?) In order to avoid this confusion we write  $\bar{2}$  for -2 and thus we write  $\log m = \bar{2}.4123$ .

Now let us explain how to use the table of logarithms to find mantissas. A table is appended at the end of this Appendix.

Observe that in the table, every row starts with a two digit number, 10, 11, 12,... 97, 98, 99. Every column is headed by a one-digit number, 0, 1, 2, ...9. On the right, we have the section called "Mean differences" which has 9 columns headed by 1, 2...9.

	0	1	2	3	4	5	6	7	8	9		1	2	3	4	5	6	7	8	9
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
61	7853	7860	7868	7875	7882	7889	7896	7803	7810	7817		1	1	2	3	4	4	5	6	6
62	7924	7931	7935	7945	7954	7959	7966	7973	7980	7987		1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055		1	1	2	3	3	4	5	6	6
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Now suppose we wish to find  $\log (6.234)$ . Then look into the row starting with 62. In this row, look at the number in the column headed by 3. The number is 7945. This means that

$$\log (6.230) = 0.7945^*$$

But we want  $\log (6.234)$ . So our answer will be a little more than 0.7945. How much more? We look this up in the section on Mean differences. Since our fourth digit is 4, look under the column headed by 4 in the Mean difference section (in the row 62). We see the number 3 there. So add 3 to 7945. We get 7948. So we finally have

$$\log (6.234) = 0.7948.$$

Take another example. To find  $\log (8.127)$ , we look in the row 81 under column 2, and we find 9096. We continue in the same row and see that the mean difference under 7 is 4. Adding this to 9096, and we get 9100. So,  $\log (8.127) = 0.9100$ .

### Finding $N$ when $\log N$ is given

We have so far discussed the procedure for finding  $\log n$  when a positive number  $n$  is given. We now turn to its converse i.e., to find  $n$  when  $\log n$  is given and give a method for this purpose. If  $\log n = t$ , we sometimes say  $n = \text{antilog } t$ . Therefore our task is given  $t$ , find its antilog. For this, we use the ready-made antilog tables.

Suppose  $\log n = 2.5372$ .

To find  $n$ , first take just the mantissa of  $\log n$ . In this case it is .5372. (Make sure it is positive.) Now take up antilog of this number in the antilog table which is to be used exactly like the log table.

\* It should, however, be noted that the values given in the table are not exact. They are only approximate values, although we use the sign of equality which may give the impression that they are exact values. The same convention will be followed in respect of antilogarithm of a number.

In the antilog table, the entry under column 7 in the row .53 is 3443 and the mean difference for the last digit 2 in that row is 2, so the table gives 3445. Hence,

$$\text{antilog } (.5372) = 3.445$$

Now since  $\log n = 2.5372$ , the characteristic of  $\log n$  is 2. So the standard form of  $n$  is given by

$$n = 3.445 \times 10^2$$

$$\text{or } n = 344.5$$

### Illustration 1

If  $\log x = 1.0712$ , find  $x$ .

**Solution:** We find that the number corresponding to 0712 is 1179. Since characteristic of  $\log x$  is 1, we have

$$\begin{aligned} x &= 1.179 \times 10^1 \\ &= 11.79 \end{aligned}$$

### Illustration 2

If  $\log x = \bar{2}.1352$ , find  $x$ .

**Solution:** From antilog tables, we find that the number corresponding to 1352 is 1366. Since the characteristic is  $\bar{2}$  i.e., -2, so

$$x = 1.366 \times 10^{-2} = 0.01366$$

## Use of Logarithms in Numerical Calculations

### Illustration 1

Find  $6.3 \times 1.29$

**Solution:** Let  $x = 6.3 \times 1.29$

$$\text{Then } \log x = \log (6.3 \times 1.29) = \log 6.3 + \log 1.29$$

Now,

$$\log 6.3 = 0.7993$$

$$\log 1.29 = 0.1106$$

$$\therefore \log x = 0.9099,$$

Taking antilog

$$x = 8.127$$

### Illustration 2

$$\text{Find } \frac{(1.23)^{1.5}}{11.2 \times 23.5}$$

$$\text{Solution: Let } x = \frac{(1.23)^{\frac{3}{2}}}{11.2 \times 23.5}$$

$$\begin{aligned}
 \text{Then } \log x &= \log \frac{(1.23)^{\frac{3}{2}}}{11.2 \times 23.5} \\
 &= \frac{3}{2} \log 1.23 - \log (11.2 \times 23.5) \\
 &= \frac{3}{2} \log 1.23 - \log 11.2 - \log 23.5
 \end{aligned}$$

Now,

$$\begin{aligned}
 \log 1.23 &= 0.0899 \\
 \frac{3}{2} \log 1.23 &= 0.13485 \\
 \log 11.2 &= 1.0492 \\
 \log 23.5 &= 1.3711 \\
 \log x &= 0.13485 - 1.0492 - 1.3711 \\
 &= -3.71455 \\
 \therefore x &= 0.005183
 \end{aligned}$$

### Illustration 3

Find  $\sqrt{\frac{(71.24)^5 \times \sqrt{56}}{(2.3)^7 \times \sqrt{21}}}$

**Solution:** Let  $x = \sqrt{\frac{(71.24)^5 \times \sqrt{56}}{(2.3)^7 \times \sqrt{21}}}$

$$\begin{aligned}
 \text{Then } \log x &= \frac{1}{2} \log \left[ \frac{(71.24)^5 \times \sqrt{56}}{(2.3)^7 \times \sqrt{21}} \right] \\
 &= \frac{1}{2} [\log (71.24)^5 + \log \sqrt{56} - \log (2.3)^7 - \log \sqrt{21}] \\
 &= \frac{5}{2} \log 71.24 + \frac{1}{4} \log 56 - \frac{7}{2} \log 2.3 - \frac{1}{4} \log 21
 \end{aligned}$$

Now, using log tables

$$\log 71.24 = 1.8527$$

$$\log 56 = 1.7482$$

$$\log 2.3 = 0.3617$$

$$\log 21 = 1.3222$$

$$\begin{aligned}
 \therefore \log x &= \frac{5}{2} \log (1.8527) + \frac{1}{4} (1.7482) - \frac{7}{2} (0.3617) - \frac{1}{4} (1.3222) \\
 &= 3.4723
 \end{aligned}$$

$$\therefore x = 2967$$

# LOGARITHMS

Table 1

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	5	9	13	17	21	26	30	34	38
											4	8	12	16	20	24	28	32	36
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	12	16	20	23	27	31	35
											4	7	11	15	18	22	26	29	33
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	11	14	18	21	25	28	32
											3	7	10	14	17	20	24	27	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
											3	7	10	13	16	19	22	25	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	19	22	25	28
											3	6	9	12	14	17	20	23	26
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	9	11	14	17	20	23	26
											3	6	8	11	14	17	19	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	6	8	11	14	16	19	22	24
											3	5	8	10	13	16	18	21	23
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	3	5	8	10	13	15	18	20	23
											3	5	8	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	17	19	21
											2	4	7	9	11	14	16	18	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
											2	4	6	8	11	13	15	17	19
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6471	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8

# LOGARITHMS

Table 1 continued

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9997	9996	0	1	1	2	2	3	3	3	4

# ANTILOGARITHMS

Table 2

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
.00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	1	2	2	2
.01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	1	2	2	2
.02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	1	2	2	2
.03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1	1	2	2	2
.04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1	2	2	2	2
.05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1	2	2	2	2
.06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1	2	2	2	2
.07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1	2	2	2	2
.08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1	2	2	2	3
.09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1	2	2	2	3
.10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1	2	2	2	3
.11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2	2	2	2	3
.12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2	2	2	2	3
.13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2	2	2	3	3
.14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2	2	2	3	3
.15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2	2	2	3	3
.16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2	2	2	3	3
.17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2	2	2	3	3
.18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2	2	2	3	3
.19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2	2	3	3	3
.20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	2	2	3	3	3
.21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	1	2	2	3	3	3
.22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	1	2	2	3	3	3
.23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	1	2	2	3	3	4
.24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	1	2	2	3	3	4
.25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	1	2	2	3	3	4
.26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	1	2	2	3	3	4
.27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	1	2	2	3	3	4
.28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	1	2	2	3	3	4
.29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	1	2	2	3	3	4
.30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	1	2	2	3	3	4
.31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	1	2	2	3	3	4
.32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	1	2	2	3	3	4
.33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	1	2	2	3	3	4
.34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3	3	4	4	5
.35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	3	3	4	4	5
.36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3	3	4	4	5
.37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3	3	4	4	5
.38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3	3	4	4	5
.39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3	3	4	5	5
.40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3	4	4	5	5
.41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	3	4	4	5	5
.42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	3	4	4	5	6
.43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3	4	4	5	6
.44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3	4	4	5	6
.45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3	4	5	5	6
.46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3	4	5	5	6
.47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3	4	5	5	6
.48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	3	4	5	6	6
.49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	3	4	5	6	6



## ANTILOGARITHMS

**Table 2 continued**

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	4	5	6	7
.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4	5	5	6	7
.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	5	6	7
.53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4	5	6	6	7
.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	6	7
.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	7	7
.56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4	5	6	7	8
.57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4	5	6	7	8
.58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4	5	6	7	8
.59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5	5	6	7	8
.60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5	6	6	7	8
.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
.62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5	6	7	8	9
.63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
.64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
.66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	9	10
.67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
.69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6	7	8	9	10
.70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6	7	8	9	11
.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
.72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6	7	9	10	11
.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6	8	9	10	11
.74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6	8	9	10	12
.75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7	8	9	10	12
.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	9	11	12
.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7	8	10	11	12
.78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7	8	10	11	13
.79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7	9	10	11	13
.80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7	9	10	12	13
.81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8	9	11	12	14
.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	12	14
.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8	9	11	13	14
.84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
.85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8	10	12	13	15
.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	12	13	15
.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9	10	12	14	16
.88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9	11	12	14	16
.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9	11	13	14	16
.90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9	11	13	15	17
.91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9	11	13	15	17
.92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	12	14	15	17
.93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10	12	14	16	18
.94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	12	14	16	18
.95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10	12	15	17	19
.96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11	13	15	17	19
.97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
.98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11	13	16	18	20
.99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20

## **Note**

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## **Note**

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