# 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

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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 projected 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.

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## 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, card-board 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

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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 stagnent 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 $Na_2S_2O_3$, adding starch solution as indicateor towards the end point. Calculate the amount of sulphide ions in the original samples from the amount of iodine used in the reaction with $H_2S$. Subtract the values of blank titration if available from the calculated values.

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## 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 puriety 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.

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## 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 laundary 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 $Cl^-$, $F^-$ and $Fe^{2+}$ 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.

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## 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 $Na_2CO_3$ 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 phenolphathalein as an indicator. Similarly, titrate other tea

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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 is 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 HC1, acetic acid solution, NaOH solution and $NH_4OH$ 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.

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## 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 HC1 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.

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## 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 $HNO_3$ 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.

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## 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 inflamable, 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.

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**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. | Dilesel 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 intermolcular attractions tend to increase with increase in molecular mass.

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In the case of alcohols, the viscosity of nine alcohols were determined and their values are given in Table-II. The viscosity of alchohols 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.

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

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

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

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

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

***(a) Solids***

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

***(b) Metals***

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

***(c) Papers***

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

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## Appendix II

### List of Chemicals and Apparatus for Chemistry Laboratory

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

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

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| 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. | Benzyaldehyde | 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. | *p*-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. | Eriochram 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. |
| 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. | *p*-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) |
| 6. | Beaker (500 mL) |
| 7. | Boiling tubes |
| 8. | Burette (50 mL) |
| 9. | Conical flask (100 mL) |
| 10. | Conical flask (150 mL) |
| 11. | Conical flask (250 mL) |
| 12. | Flat bottomed flask (1 litre) |
| 13. | Funnel (8 cm diameter) |
| 14. | Glass droppers |
| 15. | Kipp's apparatus (diameter 1000 mm) |
| 16. | Kjeldal's flask |
| 17. | Liebig's condenser |
| 18. | Measuring cylinder (10 mL) |
| 19. | Measuring cylinder (50 mL) |
| 20. | Measuring cylinder (100 mL) |
| 21. | Measuring flask (100 mL) |
| 22. | Measuring flask (250 mL) |
| 23. | Petri dish (8 cm diameter) |
| 24. | Pipette (10 mL) |
| 25. | Pipette (25 mL) |
| 26. | Round bottom flask (500 mL) |
| 27. | Round bottom flask (1 litre) |
| 28. | Separating funnel (250 mL) |
| 29. | Test tube (15 mL) |
| 30. | Thiele's tube |
| 31. | Watch glass (9 cm diameter) |
| 32. | Water aspirator weighing bottle |

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## Miscellaneous Articles

| Sl. No. | Item Description |
|---|---|
| 1. | Agar agar |
| 2. | Ammeter (0-1 amp) |
| 3. | Beehive shelf |
| 4. | Blow pipe |
| 5. | Blue glass |
| 6. | Bunsen burner |
| 7. | Burette brush |
| 8. | Burette stand (wooden) |
| 9. | Calorimeter |
| 10. | Capillary tube |
| 11. | Charcoal black |
| 12. | Chemical balance |
| 13. | Clamp |
| 14. | Connecting wires |
| 15. | Copper plate |
| 16. | Cork |
| 17. | Cork borer sets |
| 18. | Cork opener |
| 19. | Dry cell (1.5 volts) |
| 20. | Filter paper sheets (Whatman and ordinary) |
| 21. | Fractional weights |
| 22. | Funnel stand |
| 23. | Gas jar with lid |
| 24. | Glass rod |
| 25. | Glass tube |
| 26. | Glass wool |
| 27. | Glazed tile (white) |
| 28. | Ignition tube |
| 29. | Iron stand |
| 30. | Key (one way) |
| 31. | Mortar and pestle |
| 32. | Pair of tongs |
| 33. | Platinum wire |

| Sl. No. | Item Description |
|---|---|
| 34. | Polythene wash bottle (500 mL) |
| 35. | Porcelain dish |
| 36. | Reagent bottle (150 mL) |
| 37. | Reagent bottle (250 mL) |
| 38. | Reagent bottle (500 mL) |
| 39. | Reagent bottle (2500 mL) |
| 40. | Ring clamp |
| 41. | Rubber cork-all sizes |
| 42. | Rubber tubing |
| 43. | Sand paper |
| 44. | Sand bath |
| 45. | Spatula (plastic) |
| 46. | Spirit |
| 47. | Spirit lamp |
| 48. | Stop watch |
| 49. | Test tube brush |
| 50. | Test tube holder |
| 51. | Test tube stand (plastic) |
| 52. | Thermometer - ordinary (100°C and 360°C) |
| 53. | Thermometer (0–110°C and 1/10th division) |
| 54. | Thistle funnel |
| 55. | Triangular file |
| 56. | Tripod stand (iron) |
| 57. | Trough |
| 58. | Wash bottle |
| 59. | Water bath |
| 60. | Water distillation plant |
| 61. | Wax (paraffin) |
| 62. | Weight box (for chemical balance) |
| 63. | Wire gauze (asbestos centre) |
| 64. | Woulf bottle |
| 65. | Zinc plate |

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## 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 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 anddilute 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. |

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| | | | | |
|---|---|---|---|---|
| 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 $BaCl_2.2H_2O$ | 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 $KMnO_4$ with conc. 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 $Na_2HPO_4.12H_2O$ | 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 $FeCl_3.6H_2O$ | 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 $(CH_3COO)_2$ 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 $Ca(OH)_2$ | 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 $CO_2$ 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. |

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| | | | | |
|---|---|---|---|---|
| 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 $SnCl_2.2H_2O$ | 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 $(NH_4)_2Sx$ | 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. |

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## 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 β-naphthol | : | Dissolve 10 g of β-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 $SO_2$ 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.*



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## APPENDIX IV

## SOME USEFUL TABLES

### Table 1 : Fundamental physical constants

| Physical constant | Symbol | Value |
|---|---|---|
| Acceleration due to gravity | g | 9.81 $ms^{-2}$ |
| Atomic mass unit | amu | $1.66053 \times 10^{-27}$ Kg |
| Avogadro constant | $N_A$ | $6.02217 \times 10^{23}$ $mol^{-1}$ |
| Boltzmann constant | $K$ | $1.38062 \times 10^{-23}$ J $K^{-1}$ |
| Electronic charge | e | $1.602192 \times 10^{-19}$ C |
| Faraday cosntant | $F$ | $9.64867 \times 10^{4}$ C $mol^{-1}$ |
| Gas constant | R | 8.314 J $K^{-1}$ $mol^{-1}$ |
| 'Ice-point' temperature | Tice | 273.150 K |
| Molar volum of ideal gas at stp. | $V_m$ | $2.24136 \times 10^{-2}$ $m^3$ $mol^{-1}$ |
| Permittivity of a vaccuum | $E_0$ | $8.854185 \times 10^{-12}$ $Kg^{-1}$ $m^{-3}s^4$ $A^2$ |
| Plank constant | $h$ | $6.62620 \times 10^{-34}$ J s |
| Rydberg constant | $R_w$ | $1.973731 \times 10^{7}$ $m^{-1}$ |
| Standard pressure (atmosphere) | $p$ | 101325 N $m^{-2}$ |
| Triple point of water | | 273016 K |
| Velocity of light of vacuum | c | $2.997925 \times 10^{8}$ m $s^{-1}$ |

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

| Compound | mp.°C | bp.°C | Density/ Kg $m^{-3}$ (298 K) | Refractive index (nD) (293 K) | $10^4$ × Viscosity/ N s $m^{-2}$) (298 K) | $10^3$ × Surface Tension/ N $m^{-1}$ (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 |

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## 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 | $NO_3^-$ | Most cations | None |
| acetate | $CH_3COO^-$ | Most cations | Ag+ |
| chloride | $Cl^-$ | Most cations | Ag+, $Pb^{2+}$, $Hg_2^{2+}$ |
| bromide | $Br^-$ | Most cations | Ag+, $Pb^{2+}$, $Hg_2^{2+}$ |
| iodide | $I^-$, | Most cations | Ag+, $Pb^{2+}$, $Hg_2^{2+}$ |
| sulphate | $SO_4^{2-}$, | Most cations | $Br^{2+}$, $Sr^{2+}$, $Pb^{2+}$, $Ag^+$ |
| chromate | $CrO_4^{2-}$ | Most cations | $Br^{2+}$, $Sr^{2+}$, $Pb^{2+}$, $Ag^+$ |
| sulphide | $S^{2-}$, | $NH_4^+$, alkali metal cations, and alkaline earth metal cations | Most other cations |
| hydroxide | $OH^-$, | $NH_4^+$, alkali metal and alkaline earth metal and $Ba^{2+}$ and $Sr^{2+}$ | Most other cations |
| carbonate | $CO_3^{2-}$ | $NH_4^+$ and alkali metal cations | Most other cations |
| phosphate | $PO_4^{3-}$ | except $Li^+$ | |

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## Appendix V

### Elements, their Atomic Number and Molar Mass

| Element | Symbol | Atomic Number | Molar mass/ (g mol$^{-1}$) |
|---|---|---|---|
| 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$^{-1}$) |
|---|---|---|---|
| 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.

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## 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 kg/ms$^2$ = 1 N/m$^2$

**Temperature**

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

K = -273.15°C

K = °C + 273.15

°F = 1.8(°C) + 32

$$°C = \frac{°F - 32}{1.8}$$

* *Force: 1 newton (N) = 1 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°C to 15.5°C.*

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

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## Appendix VII

### Standard Potentials at 298 K in Electrochemical

| Reduction half-reaction | $E^{\ominus}$/V | Reduction half-reaction | $E^{\ominus}$/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 |
| $ClO_4^- + 2H^+ + 2e^- \longrightarrow ClO_3^- + 2H_2O$ | +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 |

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| | | | |
|---|---|---|---|
| $AgCl + e^- \longrightarrow Ag + Cl^-$ | +0.27 | $S + 2e^- \longrightarrow S^{2-}$ | –0.48 |
| $Bi^{3+} + 3e^- \longrightarrow Bi$ | +0.20 | $In^{3+} + e^- \longrightarrow In^{2+}$ | –0.49 |
| $SO_4^{2-} + 4H^+ + 2e^- \longrightarrow H_2SO_3 + H_2O$ | +0.17 | $U^{4+} + e^- \longrightarrow U^{3+}$ | –0.61 |
| $Cu^{2+} + e^- \longrightarrow Cu^+$ | +0.16 | $Cr^{3+} + 3e^- \longrightarrow Cr$ | –0.74 |
| $Sn^{4+} + 2e^- \longrightarrow Sn^{2+}$ | +0.15 | $Zn^{2+} + 2e^- \longrightarrow Zn$ | –0.76 |
| $AgBr + e^- \longrightarrow Ag + Br^-$ | +0.07 | $Cd(OH)_2 + 2e^- \longrightarrow Cd + 2OH^-$ | –0.81 |
| $Ti^{4+} + e^- \longrightarrow Ti^{3+}$ | 0.00 | $2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$ | –0.83 |
| $2H^+ + 2e– \longrightarrow H_2$ | (by definition) 0.0 | $Cr^{2+} + 2e^- \longrightarrow Cr$ | –0.91 |
| $Fe^{3+} + 3e^- \longrightarrow Fe$ | –0.04 | $Mn^{2+} + 2e^- \longrightarrow Mn$ | –1.18 |
| $O_2 + H_2O + 2e^- \longrightarrow HO_2^- + OH^-$ | –0.08 | $V^{2+} + 2e^- \longrightarrow V$ | –1.19 |
| $Pb^{2+} + 2e^- \longrightarrow Pb$ | –0.13 | $Ti^{2+} + 2e^- \longrightarrow Ti$ | –1.63 |
| $In^+ + e^- \longrightarrow In$ | –0.14 | $Al^{3+} + 3e^- \longrightarrow Al$ | –1.66 |
| $Sn^{2+} + 2e^- \longrightarrow Sn$ | –0.14 | $U^{3+} + 3e^- \longrightarrow U$ | –1.79 |
| $AgI + e^- \longrightarrow Ag + I^-$ | –0.15 | $Sc^{3+} + 3e^- \longrightarrow Sc$ | –2.09 |
| $Ni^{2+} + 2e^- \longrightarrow Ni$ | –0.23 | $Mg^{2+} + 2e^- \longrightarrow Mg$ | –2.36 |
| $V^{3+} + e^- \longrightarrow V^{2+}$ | –0.26 | $Ce^{3+} + 3e^- \longrightarrow Ce$ | –2.48 |
| $Co^{2+} + 2e^- \longrightarrow Co$ | –0.28 | $La^{3+} + 3e^- \longrightarrow La$ | –2.52 |
| $In^{3+} + 3e^- \longrightarrow In$ | –0.34 | $Na^+ + e^- \longrightarrow Na$ | –2.71 |
| $Tl^+ + e^- \longrightarrow Tl$ | –0.34 | $Ca^{2+} + 2e^- \longrightarrow Ca$ | –2.87 |
| $PbSO_4 + 2e^- \longrightarrow Pb + SO_4^{2-}$ | –0.36 | $Sr^{2+} + 2e^- \longrightarrow Sr$ | –2.89 |
| $Ti^{3+} + e^- \longrightarrow Ti^{2+}$ | –0.37 | $Ba^{2+} + 2e^- \longrightarrow Ba$ | –2.91 |
| $Cd^{2+} + 2e^- \longrightarrow Cd$ | –0.40 | $Ra^{2+} + 2e^- \longrightarrow Ra$ | –2.92 |
| $In^{2+} + e^- \longrightarrow In^+$ | –0.40 | $Cs^+ + e^- \longrightarrow Cs$ | –2.92 |
| $Cr^{3+} + e^- \longrightarrow Cr^{2+}$ | –0.41 | $Rb^+ + e^- \longrightarrow Rb$ | –2.93 |
| $Fe^{2+} + 2e^- \longrightarrow Fe$ | –0.44 | $K^+ + e^- \longrightarrow K$ | –2.93 |
| $In^{3+} + 2e^- \longrightarrow In^+$ | –0.44 | $Li^+ + e^- \longrightarrow Li$ | –3.05 |

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## 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 $m^{th}$ 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

$\log_2 8 = 3$, Since $2^3 = 8$

$\log_3 9 = 2$, Since $3^2 = 9$

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

$\log_7 1 = 0$, 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 $a^x = m$, $a^y = n$

Hence $mn = a^x.a^y = a^{x+y}$

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 $\log_a m = x$, $\log_a n = y$

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

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 $a^x = m$

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

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:

$\log_{10} 10 = 1$, since $10^1 = 10$

$\log_{10} 100 = 2$, since $10^2 = 100$

$\log_{10} 10000 = 4$, since $10^4 = 10000$

$\log_{10} 0.01 = -2$, since $10^{-2} = 0.01$

$\log_{10} 0.001 = -3$, since $10^{-3} = 0.001$

and $\log_{10} 1 = 0$ since $10^0 = 1$

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



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

(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

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

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

$\log n = \log m + \log 10^p$

$= \log m + p \log 10$

$= p + \log m$

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 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

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

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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 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 = 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.*



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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,

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

$n = 3.445 \times 10^2$

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

$x = 1.179 \times 10^1$

$= 11.79$

**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 × 1.29

**Solution:** Let x = 6.3 × 1.29

Then log x = log (6.3 × 1.29) = log 6.3 + log 1.29

Now,

log 6.3 = 0.7993

log 1.29 = 0.1106

∴ log x = 0.9099,

Taking antilog

x = 8.127

**Illustration 2**

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

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

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Then $\log x = \log \dfrac{(1.23)^{\frac{3}{2}}}{11.2 \times 23.5}$

$= \dfrac{3}{2} \log 1.23 - \log (11.2 \times 23.5)$

$= \dfrac{3}{2} \log 1.23 - \log 11.2 - 23.5$

Now,

$\log 1.23 = 0.0899$

$\dfrac{3}{2} \log 1.23 = 0.13485$

$\log 11.2 = 1.0492$

$\log 23.5 = 1.3711$

$\log x = 0.13485 - 1.0492 - 1.3711$

$= \overline{3}.71455$

$\therefore x = 0.005183$

**Illustration 3**

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

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

Then $\log x = \dfrac{1}{2} \log \left[\dfrac{(71.24)^5 \times \sqrt{56}}{(2.3)^7 \times \sqrt{21}}\right]$

$= \dfrac{1}{2} [\log (71.24)^5 + \log \sqrt{56} - \log (2.3)^7 - \log \sqrt{21}]$

$= \dfrac{5}{2} \log 71.24 + \dfrac{1}{4} \log 56 - \dfrac{7}{2} \log 2.3 - \dfrac{1}{4} \log 21$

Now, using log tables

$\log 71.24 = 1.8527$

$\log 56 = 1.7482$

$\log 2.3 = 0.3617$

$\log 21 = 1.3222$

$\therefore \log x = \dfrac{5}{2} \log (1.8527) + \dfrac{1}{4} (1.7482) - \dfrac{7}{2} (0.3617) - \dfrac{1}{4} (1.3222)$

$= 3.4723$

$\therefore x = 2967$

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# 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<br>4 | 9<br>8 | 13<br>12 | 17<br>16 | 21<br>20 | 26<br>24 | 30<br>28 | 34<br>32 | 38<br>36 |
| 11 | 0414 | 0453 | 0492 | 0531 | 0569 | 0607 | 0645 | 0682 | 0719 | 0755 | 4<br>4 | 8<br>7 | 12<br>11 | 16<br>15 | 20<br>18 | 23<br>22 | 27<br>26 | 31<br>29 | 35<br>33 |
| 12 | 0792 | 0828 | 0864 | 0899 | 0934 | 0969 | 1004 | 1038 | 1072 | 1106 | 3<br>3 | 7<br>7 | 11<br>10 | 14<br>14 | 18<br>17 | 21<br>20 | 25<br>24 | 28<br>27 | 32<br>31 |
| 13 | 1139 | 1173 | 1206 | 1239 | 1271 | 1303 | 1335 | 1367 | 1399 | 1430 | 3<br>3 | 6<br>7 | 10<br>10 | 13<br>13 | 16<br>16 | 19<br>19 | 23<br>22 | 26<br>25 | 29<br>29 |
| 14 | 1461 | 1492 | 1523 | 1553 | 1584 | 1614 | 1644 | 1673 | 1703 | 1732 | 3<br>3 | 6<br>6 | 9<br>9 | 12<br>12 | 15<br>14 | 19<br>17 | 22<br>20 | 25<br>23 | 28<br>26 |
| 15 | 1761 | 1790 | 1818 | 1847 | 1875 | 1903 | 1931 | 1959 | 1987 | 2014 | 3<br>3 | 6<br>6 | 9<br>8 | 11<br>11 | 14<br>14 | 17<br>17 | 20<br>19 | 23<br>22 | 26<br>25 |
| 16 | 2041 | 2068 | 2095 | 2122 | 2148 | 2175 | 2201 | 2227 | 2253 | 2279 | 3<br>3 | 6<br>5 | 8<br>8 | 11<br>10 | 14<br>13 | 16<br>16 | 19<br>18 | 22<br>21 | 24<br>23 |
| 17 | 2304 | 2330 | 2355 | 2380 | 2405 | 2430 | 2455 | 2480 | 2504 | 2529 | 3<br>3 | 5<br>5 | 8<br>8 | 10<br>10 | 13<br>12 | 15<br>15 | 18<br>17 | 20<br>20 | 23<br>22 |
| 18 | 2553 | 2577 | 2601 | 2625 | 2648 | 2672 | 2695 | 2718 | 2742 | 2765 | 2<br>2 | 5<br>4 | 7<br>7 | 9<br>9 | 12<br>11 | 14<br>14 | 17<br>16 | 19<br>18 | 21<br>21 |
| 19 | 2788 | 2810 | 2833 | 2856 | 2878 | 2900 | 2923 | 2945 | 2967 | 2989 | 2<br>2 | 4<br>4 | 7<br>6 | 9<br>8 | 11<br>11 | 13<br>13 | 16<br>15 | 18<br>17 | 20<br>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 |

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## 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 | 7768 | 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 |

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# 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 | 2 | 2 | 2 | 3 | 3 | 3 |
| .22 | 1660 | 1663 | 1667 | 1671 | 1675 | 1679 | 1683 | 1687 | 1690 | 1694 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 |
| .23 | 1698 | 1702 | 1706 | 1710 | 1714 | 1718 | 1722 | 1726 | 1730 | 1734 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 |
| .24 | 1738 | 1742 | 1746 | 1750 | 1754 | 1758 | 1762 | 1766 | 1770 | 1774 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 |
| **.25** | 1778 | 1782 | 1786 | 1791 | 1795 | 1799 | 1803 | 1807 | 1811 | 1816 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 |
| .26 | 1820 | 1824 | 1828 | 1832 | 1837 | 1841 | 1845 | 1849 | 1854 | 1858 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 |
| .27 | 1862 | 1866 | 1871 | 1875 | 1879 | 1884 | 1888 | 1892 | 1897 | 1901 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 |
| .28 | 1905 | 1910 | 1914 | 1919 | 1923 | 1928 | 1932 | 1936 | 1941 | 1945 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| .29 | 1950 | 1954 | 1959 | 1963 | 1968 | 1972 | 1977 | 1982 | 1986 | 1991 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| **.30** | 1995 | 2000 | 2004 | 2009 | 2014 | 2018 | 2023 | 2028 | 2032 | 2037 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| .31 | 2042 | 2046 | 2051 | 2056 | 2061 | 2065 | 2070 | 2075 | 2080 | 2084 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| .32 | 2089 | 2094 | 2099 | 2104 | 2109 | 2113 | 2118 | 2123 | 2128 | 2133 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| .33 | 2138 | 2143 | 2148 | 2153 | 2158 | 2163 | 2168 | 2173 | 2178 | 2183 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 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 |

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# 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 | 42S6 | 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 | 1314 | |
| .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 |

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