1.11 SUMMARY

In this unit, we discussed the safety measures to be adopted while working in a chemistry laboratory. We explained some of the techniques which are useful in performing the experiments of this course. We also discussed the relevant calculations and the apparatus for these experiments.

1.12 ANSWERS

Self Assessment Questions

1) Titrimetric analysis consists in determining the volume of a standard solution which is required to react completely with a known volume of the solution of a substance being estimated.

2) i) Titration using phenolphthalein as an indicator

   ii) Titration using conductometer or mV/pH meter.

3) An analytical balance can be used for weighing masses to a precision limit of 0.2 mg.

4) 18.3562 g

5) As per Eq. 1.5, molarity $= \dfrac{1000\,m}{M_m\,V}$

$$= \frac{1000 \times 2}{40 \times 500}\ \text{M}$$

$$= 0.1\ \text{M}$$

6) i) Sodium carbonate

   ii) sodium oxalate

7) CO_3^{2-} (from Na_2CO_3) + $2H^+$ (from HCl) $\longrightarrow$ H_2CO_3

Let M_1 and M_2 stand for the molarities of sodium carbonate and hydrochloric acid, respectively while V_1 and V_2 refer to the equivalent volumes of sodium carbonate and hydrochloric acid, respectively. In comparison to Eq. 1.13.

$$\frac{M_1 V_1}{M_2 V_2} = \frac{1}{2}$$

or $\quad 2M_1 V_1 = M_2 V_2$

8) Mixtures of different compositions of phenol and water are to be taken in different test tubes and heated in water bath to study the miscibility temperature in each case.

UNIT 2 HANDLING OF DATA

Structure

2.1 INTRODUCTION

In Unit 1, we studied some of the laboratory techniques which are to be used in this course. As part of this, we discussed the methods of expression of concentration and, titrimetric calculation. These two are, in fact, part of data handling techniques. Handling of data consists of processing the experimental data and expressing the values of the physical parameters with proper magnitude and units. Processing of data includes stepwise calculation to obtain the value of a parameter and representation of results using tables or graphs.

In this unit, we shall discuss the basic and derived SI units. We shall explain the principles to be followed in expressing a number in scientific notation. We shall define the term, significant figure. We shall explain how to maintain significant figures while doing calculations of various types such as addition, subtraction, multiplication, division, taking logarithms and antilogarithms etc. We shall finally discuss how to record the observations, tabulate the data and plot the graphs.

Objectives

After studying this unit, you should be able to

- state the SI units of basic and derived physical quantities,
- arrive at the SI units of a physical quantity,

- write numbers using scientific notation,
- calculate the significant figures in a number,
- carry out calculations maintaining significant figures,
- state the important features concerning the maintenance of laboratory note book, and
- explain the methods of tabulation of data and plotting of graphs.

2.2 SI UNITS

Till recently in the scientific world, mainly two systems of units had been in common use. One is c.g.s. (centimetre, gram, second) which was more commonly used over the European continent and the other is f.p.s. (foot, pound and second) prevalent in England. A common system of units helps in exchanging the scientific facts and ideas originating from different countries. It is better still if the system of units could be derived from the scientific formulae or fundamental constants. This long felt need for a common system of scientific units was realised at a meeting called General Conference on Weights and Measures in 1960. At this meeting, the international scientific community agreed to adopt common units of measurements known as International System of Units. This is abbreviated as SI units from the French name, ***Systeme Internationale.*** In this section, we shall first state the SI units for a few basic and derived quantities. Then we shall explain the prefixes used to change the order of magnitude of the SI units. Also we shall state the rules for representing the SI units.

2.2.1 Basic Units

There are seven basic physical quantities, from which all other physical quantities can be derived. The units of these basic physical quantities are called **basic units.** The names of these quantities along with their symbols, SI units and the symbols of SI units are given in Table 2.1. Each of these seven quantities is regarded as having its own dimension. The symbol of a quantity represents its dimension as given in column (ii) of Table 2.1. The dimensions of basic quantities are useful in defining the derived physical quantities, which we shall study in subsection 2.2.2. We will be using the symbols given in column (ii) of Table 2.1 to refer to the dimensions of the basic quantities.

Table 2.1 : Basic Physical Quantities and Their SI Units

Physical Quantity (i)	Symbol of Quantity (ii)	Name of the SI Unit (iii)	Symbol of the SI Unit (iv)
Length	l	metre	m
Mass	m	kilogram	kg
Time	t	second	s
Electric current	I	ampere	A
Temperature	T	kelvin	K
Luminous intensity	I_r	candela	cd
Amount of substance	n	mole	mol

Note that *m* (italicised) is the symbol for mass of an object, while m (roman) is the symbol of SI unit, metre.

We are not going to define kilogram, metre etc. since our aim is to use these units and not to establish the basis of these units.

2.2.2 Derived Units

All other physical quantities are regarded as being derived from the above seven basic quantities by definitions involving multiplication, division, differentiation and integration. Such quantities and their units are called **derived physical quantities and derived units**, respectively. In Tables 2.2 and 2.3, the derived SI units without and with special names are given.

For convenience, we shall use molarity (mol dm^{-3}) units for referring to the concentration of solutions

1 M = 1 mol dm^{-3} = 1000 mol m^{-3}

Table 2.2 : Derived SI Units Without Special Names

Physical Quantity (i)	Definition (ii)	Dimensional formula (iii)	Name of the SI Unit (iv)	Symbol of the SI Unit (v)
Area	Length × length	l^2	square metre	m^2
Volume	Length × length × length	l^3	cubic metre	m^3
Density	Mass/volume	ml^{-3}	kilogram per cubic metre	kg m^{-3}
Velocity	Displacement/Time	lt^{-1}	metre per second	m s^{-1}
Acceler-ration	$\frac{\text{(Change in velocity)}}{\text{Time}}$	lt^{-2}	metre per second squared	m s^{-2}
Molar mass	$\frac{\text{Mass}}{\text{(Amount of the Substance)}}$	mn^{-1}	kilogram per mole	kg mol^{-1}
Concen-tration	Amount/Volume	nl^{-3}	mole per cubic metre	mol m^{-3}

The definitions given for area and volume are of general type, although specific formulae are to be used depending on the shape or surface of an object.

Table 2.3 : Derived SI Units Having Special Names

Physical Quantity (i)	Definition (ii)	Dimensional formula (iii)	Name of the SI Unit (iv)	Symbol of the SI Unit (v)
Force	Mass × acceleration	mlt^{-2}	newton	N or kg m s^{-2}
Pressure	Force/Area	mlt^{-2}/l^2 $=ml^{-1}t^{-2}$	pascal	Pa or kg m s^{-2}/m^{-2} or kg m^{-1} s^{-2}
Energy or work	Force × distance	$mlt^{-2}l$ $=ml^2t^{-2}$	joule	J or N m or Pa m^3 or kg m^2 s^{-2}
Electic charge	$\begin{pmatrix}\text{Electric}\\\text{current}\end{pmatrix}$ × time	It	coulomb	C or A s
Electric potential difference	$\frac{\text{Electrical energy}}{\text{Electric charge}}$	$\frac{ml^2t^{-2}}{It}$ $= ml^2I^{-1}t^{-3}$	volt	V or J C^{-1} or kg m^2 A^{-1} s^{-3}
Electric resistance	$\frac{\text{(Electric Potential difference)}}{\text{(Electric Current)}}$	$\frac{ml^2I^{-1}t^{-3}}{I}$ $=ml^2I^{-2}t^{-3}$	ohm	Ω or V A^{-1} or kg m^2 A^{-2} s^{-3}
Electric conductance	1/(Electric resistance)	$1/ml^2I^{-2}t^{-3}$ $= I^2t^3m^{-1}l^{-2}$	siemens	S or A V^{-1} or A^2 s^3 kg^{-1} m^{-2}
Frequency	$\frac{\text{(Number of waves or cycles)}}{\text{Time}}$	$\frac{1}{t}$	hertz	Hz or s^{-1}

From Tables 2.1, 2.2 and 2.3, you can find a direct correspondence between the dimensions of a physical quantity and the symbols of its SI units. For example, see how from the dimensions of acceleration, its SI units have been worked out below:

Dimensions of acceleration $= lt^{-2}$ [column (iii) of Table 2.2]
Units of acceleration $=$ m s^{-2} [columns (ii) and (iv) of Table 2.1] (in terms of symbols)

Next we shall discuss how the dimensions and the units of a physical quantity can be obtained.

Deduction of the SI Units of a Physical Quantity

We can derive the dimensions and the units of a physical quantity, provided a mathematical relationship is available between this physical quantity and other physical quantities of known dimensions. Let us illustrate this by means of the following examples:

Example 1

Suppose we want to find the dimensions and the units of the **gas constant**, R. The mathematical relationship to be used for this is the ideal gas equation, Eq. 2.1.

$$\left.\begin{array}{r}\text{Pressure} \times \text{volume} = \text{Amount of the substance} \times \\ \text{gas constant} \times \text{temperature}\end{array}\right\} \quad \ldots (2.1)$$

Rearranging this,

$$R = \frac{\text{Pressure} \times \text{volume}}{\text{Amount of the substance} \times \text{temperature}} \quad \ldots (2.2)$$

The dimensions of the quantities in the right hand side of Eq. 2.2 are mentioned in Tables 2.1–2.3. We used the dimensions of these quantities to derive the dimensions and the units of R as shown below :

$$\text{Dimensions of } R = \text{Dimensions of } \left[\frac{\text{Pressure} \times \text{volume}}{\text{Amount of the substance} \times \text{temperature}}\right]$$

$$= \frac{ml^{-1}\,t^{-2}\,l^3}{nT} = (ml^2\,t^{-2})\,(n^{-1})\,(T^{-1})$$

Hence, the units of R = joule mole^{-1} kelvin^{-1}.

Generally we represent the SI units of a physical quantity in terms of symbols in this course.

(Using the units corresponding to the dimensions mentioned in Tables 2.1-2.3)

Thus, R has the dimensions of (energy) (amount of the substance)$^{-1}$ (temperature)$^{-1}$ and the units, J mol^{-1} K^{-1}.

Example 2

We can derive the SI units of surface tension using the following relationship :

In a detailed way, you shall study surface tension and viscosity in Units 4 and 5 of this course.

Surface tension = Force per unit length (acting perpendicular to a liquid surface)

$$= \frac{\text{Force}}{\text{Length}} \quad \text{(relationship is written to arrive at the dimensions)}$$

Dimensions of surface tension $= mlt^{-2}/l$ or mt^{-2}

Units of surface tension $= \text{N m}^{-1}$ or kg s^{-2}
(in terms of corresponding units)

Example 3

Let us now derive the SI units of coefficient of viscosity. The coefficient of viscosity is defind as the (tangential) force (F) per unit area (A) offered by a liquid layer to create a unit velocity gradient (v/l). Velocity gradient means drop in velocity (v) per unit length. Unit velocity gradient means a drop in velocity of 1 m s^{-1} per every 1 m length.

Hence, coefficient of viscosity $=(F/A)/(v/l)$

Dimensions of coefficient of viscosity $=(mlt^{-2}/l^2)/(l/tl)$

$= (ml^{-1}t^{-2})(t)$

Units of coefficient of viscosity =Pa s (using corresponding units)

In general, the following hints would be useful in the deduction of the unit of a quantity (which we name as test quantity):

i) Write an equation relating the test quantity to other quantities of known dimensions.

ii) Rearrange this equation such that only the test quantity is on the left hand side and others are on the right hand side.

iii) Substitute the dimensions of the quantities on the right hand side and simplify.

iv) Write down the units corresponding to the simplified dimensions, using Tables 2.1–2.3.

Use the above hints and work out the following SAQs.

SAQ 1

Derive the units of the second order rate constant (k) using the following equation :
Reaction rate $=k$ [reactant]^2
where reaction rate denotes the concentration of the reactant used up per unit time and [reactant] is the concentration of the reactant. Note that the concentration is to be expressed in molarity.

....

....

....

....

SAQ 2

From the equation.

kinetic energy $=1/2 \times$ mass $\times$ (velocity)^2, derive the units of kinetic energy.

....

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2.2.3 SI Prefixes

We now discuss how to overcome the difficulty of expressing the units of physical quantities, which are either very large or very small, as compared to the SI units. We add a prefix to the SI unit such that the magnitude of the physical quantity of a substance can be expressed as a convenient number.

Prefixing of SI units helps in expressing a physical quantity, large or small, as a convenient number.

Example : $7{\cdot}4 \times 10^{-11}$m

$= 74 \times 10^{-12}$ m

$=74$ pm

For example, the bond distance in hydrogen molecule is 7.4×10^{-11} m. We express it conveniently as 74 pm where pico is the SI prefix and p is its symbol. The list of SI prefixes it given in Table 2.4 and it is possible to change the order of magnitude of any unit using this table.

Table 2.4 : SI Prefixes

Submultiple	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-1}	deci	d	10	deca	da
10^{-2}	centi	c	10^{2}	hecto	h
10^{-3}	milli	m	10^{3}	kilo	k
10^{-6}	micro	μ	10^{6}	mega	M
10^{-9}	nano	n	10^{9}	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f	10^{15}	peta	P
10^{18}	atto	a	10^{18}	exa	E

More examples for usage of prefixes are given below :

$$10^3 \text{ m} = 1 \text{ km}; 10^{-9} \text{ s} = 1 \text{ ns}$$

The unit for mass is kg which is already prefixed. We do not add a second prefix but rather use a single prefix on the unit gram. Thus, to represent 10^{-9} gram, the unit used is ng and not pkg. For 10^{-3} gram, mg is used not μkg.

SAQ 3

Write down the following with proper SI unit symbols and prefixes :

(a) 10^{-9} metre (b) 10^{-12} second (c) 10^{3} pascal

....

....

....

....

SAQ 4

Write down 0.015×10^{-4} S using proper SI prefix.

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2.2.4 Grammatical Rules for Representing SI Units

The following rules would be of immense help to you while using SI units :

i) The symbol of a unit is never to be used in plural form. Writing 10 kilograms as 10 kg is correct but not as 10 kgs.

Three no's in SI units:
No plurals:
No full stops (except at the end of a sentence):
No dashes.

ii) In normal usage, full stop is used to indicate the end of a sentence or the presence of an abbreviation. To denote the symbol of SI unit as an abbreviation by using a full stop is incorrect; but, if the SI unit is at the end of a sentence, then the full stop can be used.

iii) When there is a combination of units, there should be a space between the symbols. If the units are written without leaving any space, the first letter is taken as a prefix. Thus, m s represents metre second whereas ms stands for millisecond.

iv) Always leave a space between the magnitude and the unit symbol of a physical quantity. For example, writing 0.51 kg is correct but not 0.51kg.

v) Symbol of the unit derived from a proper name is represented using capital letters but not the name of the unit (Table 2.3). For example, writing 100 newton or 100 N is correct but not 100 Newton or 100 n.

vi) For numbers less than unity, zero must be inserted to the left of the decimal point. Thus, writing 0.23 kg is correct but not .23 kg.

vii) For larger numbers exceeding five figures, one space after every three digits (counting from the right end) must be left blank. Commas should not be used to space digits in numbers. For example 15 743 231 N is correct but not 15, 743, 231 N. It is preferable to use proper SI prefixes.

In cm unit, c (centi. 10^{-2}) is the prefix of the unit, m (metre).

viii) The degree sign is to be omitted before K while representing temperature. For example, 298 K is correct but not 298° K.

ix) You should not mix words and symbols for representing SI units. For example, it is proper to write N m^{-2} or newton per square metre and not N per square metre.

x) Exponents (or powers) operate on prefixes also. Let us derive the relationship between cm^3 and m^3 using the relation, 1 cm $= 10^{-2}$ m.

$1 \text{ cm}^3 = (1 \text{ cm})^3 = (10^{-2} \text{ m}) \times (10^{-2} \text{ m}) \times (10^{-2} \text{ m}) = 10^{-6} \text{ m}^3$

Thus, 1 cm^3 is eqal to 10^{-6} m^3 but not to 10^{-2} m^3 or 10^{-3} m^3

xi) To show that a particular unit symbol has a negative exponent, one may be tempted to use the sign "/ ", known as solidus. It is better to avoid the usage of this sign and if used, no more than one should be employed. For example, representing pascal (kg m^{-1} s^{-2})as kg/m s^2 is allowed but not as kg/m/s^2.

xii) The physical quantity 'amount' should not be called ' number of moles' just as the physical quantity 'mass' , is not called number of kilograms.

So far, we studied some rules for writing SI units. Let us now discuss the dimensions of some mathematical functions which are useful in studying this course.

While representing the relationship among the physical quantities of substances, we often come across the mathematical functions like $\sin x$, and $\ln x$. It is to be kept in mind that trigonometric functions ($\sin x$, $\cos x$ etc.) exponential functions functions (e^x or e^{-x}) and logarithmic functions ($\ln x$ or $\log x$) are dimensionless quantities and hence, have no units.

You can understand the validity of this statement, once you recapitulate the definitions of these functions. We shall illustrate this for the functions, $\sin x$ and e^x.

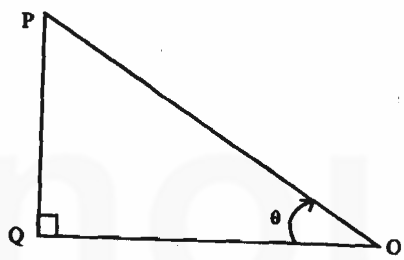

Fig. 2.1 : Right angled triangle

From the right-angled triangle PQO (Fig. 2.1),

$$\sin \theta = \frac{\text{Length of PQ}}{\text{Length of OP}}$$

Evidenly $\sin \theta$ is dimensionless and has no unit. The same is true of other trigonometric functions also.

As an illustration for the exponential series, let us consider e^x

$$e^x = 1 + \frac{x}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \cdots$$

Since addition or subtraction must be done between quantities of same dimensions, $1, x, x^2, x^3$ .... etc. in the above series must all be of the same dimensions. This indicates that x and e^x are dimensionless and unitless. Again this is true of e^{-x} and $\ln x$ or $\log x$ also.

We have to be careful in using dimensionless quantities such as logarithmic quantities in calculations. For example, while using logarithmic quantities in calculations, it is necessary to divide the physical quantities by the respective units. See the following examples:

i) $\log [H^+]/M$: $[H^+]$ has molarity unit and it is divided by M to render it dimensionless; this is used in SAQ 12 of this unit in subsec 2.4.4.

ii) $\log (V_\infty - V_t)/\text{cm}^3$: V_∞ and V_t are volumes of nitrogen gas at infinite time and at time t; in order to render $(V_\infty - V_t)$ dimensionless, it is divided by cm^3 unit. See Example 14 in Sec. 2.6 of this unit.

$e^x = 1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \cdots = 2.718$

1! is to be read as ' factorial' 1;

2! is to be read as 'factorial' 2;

3! is to be read as 'factorial 3; etc.

Also $1! = 1$; $2! = 1 \times 2$;

$3! = 1 \times 2 \times 3$;

$4! = 1 \times 2 \times 3 \times 4$; etc.

Further, '.....' refers to the other members of the exponential series.

SAQ 5

State the SI units of R using a solidus.

. . . .

. . . .

. . . .

2.3 SOME USEFUL MATHEMATICAL OPERATIONS

It is useful to recapitulate some mathematical operations involving the exponents (or powers) as given in Table 2.5.

Table 2.5 : Operations Involving the Exponents

Operations	Formula		Example
Multiplication	$N^x N^y = N^{x+Y}$		$10^5 \times 10^3 = 10^8$
Division	$N^x/N^y = N^{x-y}$		$10^5/10^3 = 10^2$
Raising to a power	$(N^x)^y = N^{xy}$		$(10^5)^3 = 10^{15}$
Taking a power root	$^y\sqrt{N^x} = N^{x/y}$	(i)	$2\sqrt{10^8} = 10^{8/2} = 10^4$
		(ii)	$3\sqrt{10^{12}} = 10^{12/3} = 10^4$

Having seen the exponential operations, let us see how to express the numbers in scientific notation.

2.3.1 Scientific Notation

Usually during multiplication and division, we come across numbers greater than 10 or less than 1. It is convenient to express such numbers in scientific notation. You may have studied this in your earlier classes. For transforming a number into scientific notation, use the following steps:

'Exponent' means 'power' of a number.

In case of integers (such as 307 or 2325 given in Table 2.6), the decimal is assumed to be present after the last digit. Thus in 307, the decimal is assumed to be present after 7; to convert it into scientific notation, the decimal is taken two places to the left, i.e., before 7 and 0. Hence, the exponent is +2 (or simply 2).

$307 = 3.07 \times 10^2$

Similarly $2325 = 2.325 \times 10^3$

[The decimal assumed to be present after 5 is taken three places to the left before 5, 2 and 3.]

i) Write the number with the decimal after the first nonzero digit. This is called the coefficient term.

ii) Multiply the number written in (i) by 10 raised to an integral exponent; this exponent is equal to the number of spaces the decimal has to be moved to bring it after the first nonzero digit. The exponent is positive if the decimal is moved to the left (the number is 10 or greater); the exponent is negative if the decimal is moved to the right (the number is less than 1).

The examples given in Table 2.6 should help you in understanding the above steps.

Table 2.6 : Scientific Notation for Numbers

Number	First nonzero digit	Decimal movement	Scientific notation	Coefficient term	Exponent
307	3	2 places to the left	3.07×10^2	3.07	2
2325	2	3 places to the left	2.325×10^3	2.325	3
0.00607	6	3 places to the right	6.07×10^{-3}	6.07	–3

Cont..

0.04325	4	2 places to the right	4.325×10^{-2}	4.325	–2
30700	3	4 places to the left	3.07×10^{4}	3.07	4
232500	2	5 places to the left	2.325×10^{5}	2.325	5

The numbers between 1 and 10 do not require the scientific notation. Thus the number, 3.2, can be written as such; its scientific notation is 3.2×10^0 and, $10^0 = 1$.

Remember that 'ln' means **natural logarithm** and it is to the base e; and, 'log' means **common logarithm** and it is to the base 10. These two logarithmic functions are related as follows:

$\ln x = 2.303 \log x$

In this course, we make use of logarithm to the base 10 only for calculations.

2.3.2 Using the Table of Logarithms

Often you have to use the table of logarithms during calculations. You may be knowing

- how to obtain the logarithm of a number and also
- how to obtain the number from its logarithm through the usage of antilogarithms. It is useful to recall the rules stated in Table 2.7 while using a logarithmic table.

Table 2.7: Rules Useful in Evaluating Logarithmic Expressions

	Rule		Example
(i)	$\log m^a = a \log m$	(i)	$\log 10^3 = 3 \log 10$
			$= 3 \times 1 = 3$
		(ii)	$\log 10^{-3} = -3 \log 10$
			$= -3 \times 1 = -3$
(ii)	$\log mn = \log m + \log n$	(i)	$\log 567.0$
			$\log 5.670 \times 10^2$
			$= \log 5.670 + \log 10^2$
			$= \log 5.670 + 2 \log 10$
			$= 0.7536 + 2 = 2.7536$
		(ii)	$\log 0.002291$
			$= \log 2.291 \times 10^{-3}$
			$= \log 2.291 + \log 10^{-3}$
			$= 0.3600 - 3 \log 10$
			$= 0.3600 - 3$ or $\bar{3}.3600 = -2.6400$
(iii)	$\log m/n = \log m - \log n$		$\log (5.612/1.608)$
			$= \log 5.612 - \log 1.608$
			$= 0.7492 - 0.2062 = 0.5430$
(iv)	$\log m/n = -\log n/m$		$\log (1.608/5.612)$
	$= -(\log n - \log m)$		$= -[\log 5.612/1.608]$
			$= -0.5430$ (or $\bar{1}.4570$)
(v)	$N = e^Y$		$7.389 = e^2$
	$\log_e N = \ln N = \ln e^Y$		$\ln 7.389 = \ln e^2$
	$= y \ln e = y$		$= 2 \ln e$
			$= 2 \times 1$
			$= 2$*

*The answer '2' has to be written as 2.000 for keeping the significant figures. We shall discuss this in Sec. 2.4 of this unit.

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

$\log_{10} 1 = \log 1 = 0$, since $10^0 = 1$

Logarithm of a number greater than 1 is positive.

Logarithm of a positive fraction is negative.

When you want to see logarithm of a quantity such as m/n where m (the numerator) is greater than n (the denominator), use rule (iii). On the other hand, if m is less than n, then use rule (iv). Try to understand the examples given for rules (iii) and (iv) in Table 2.7.

Rule (v) involving logarithm to the base e is given only for showing the similarity with logarithm to the base 10

$\log_e e = \ln e = 1$

$\log_e 1 = \ln 1 = 0$

In case you have any problem in understanding the examples worked out in Table 2.7 or in finding the logarithm of a number, use the following steps, which are illustrated in Table 2.8.

i) Write the scientific notation of the given number.

ii) The **mantissa** is equal to the logarithm of the coefficient term; you can see logarithms from the tables given towards the end of this block.

iii) The characteristic is equal to the exponent (or power of 10) in the scientific notation.

iv) Add the characteristic and mantissa as per rule (ii) explained in Table 2.7; the sum is the logarithm of the given number.

For the number, 607.0, the logarithm is 2.7832. Here '2' is the characteristic and "0.7832" is the mantissa. For explanation, see Table 2.8.

While expressing the logarithm of a number less than one, the characteristic (and the logarithmic value) can be expressed either with

(i) a negative sign or

(ii) with a bar sign (i..e. "—" sign over the number representing the characteristic).

If you are not aware of using the table of logarithms and antilogarithms, consult your c o

The former is useful in representing the logarithm of a number such as in pH calculations in Experiment 8 of Block 3 of this course. The latter is useful while carrying out multiplication or division.

A few examples are discussed in Table 2.8.

Table 2.8 : Finding the Logarithm of Given Number

Number	Scientific notation	Coefficient	Mantissa = log (coefficient)	Exponent	Characteristic =Exponent	Logarithm of the number =characteristic +mantissa
8.000	8.000×10^0	8.000	log 8.000 =0.9031	0	0	0+0.9031 =0.9031
80.00	8.000×10^1	8.000	log 8.000 =0.9031	1	1	1 +0.9031 =1.9031
607.0	6.070×10^2	6.070	log 6.070 =0.7832	2	2	2 +0.7832 =2.7832
2325	2.325×10^3	2.325	log 2.325 = 0.3664	3	3	0.3664 + 3 = 3.3664
0.8000	8.000×10^{-1}	8.000	log 8.000 = 0.9031	–1 or $\bar{1}$	–1	–1 + 0.9031 = –0.0969 (or$\bar{1}$.9031)
0.006070	6.070×10^{-3}	6.070	log 6.070 = 0.7832	– 3 or $\bar{3}$	–3	0.7832 – 3 = –2.2168 (or $\bar{3}$.7832)

$\bar{1}$ is to be read as "one bar"

From Table 2.8, you can see that the logarithm of a number greater than 1 is positive; the logarithm of a number less than 1 (but greater than 0) is negative. It is so since log 1 is zero. It is meaningless to look for the logarithm of a negative quantity.

2.3.3 Finding the Number from their Logarithms

Eq. 2.3 is useful in finding out 10^x whether x is positive or negative.

To find a number from its logarithmic value, we have to find out the antilogarithm. We shall use the following relationships while looking for antilogarithms.

$\log N = x$

$N = 10^x = \text{antilog}\, x$ . . . (2.3)

Let us see some examples,

i) When x is positive

When the exponent x is positive, use the following steps for finding N as per Eq. 2.3.

i) The digit(s) before the decimal in the given logarithmic value should be identified as the characteristic and must be converted into the exponent term.

Exponent term $= 10^{(\text{characteristic})}$ . . . (2.4)

ii) The digit(s) after the decimal in the logarithmic value should be taken as the mantissa and must be converted into the coefficient term by looking for the antilogarithms given towards the end of this block.

Coefficient term = antilog (mantissa) . . . (2.5)

iii) The answer is obtained by multiplying the coefficient term and the exponent term.

Answer = Coefficient term × exponent term . . . (2.6)

Example 4

Finding N if $\log N = 1.5100$

In this case, characteristic = 1 and,
mantissa = 0.5100

Using Eq. 2.4, the exponent term $= 10^{(\text{characteristic})} = 10^1$

Using Eq. 2.5, the coefficient term = antilog (mantissa)

= antilog 0.5100

= 3.236

Using Eq. 2.6, $N = 3.236 \times 10^1$ or 32.26

Example 5

Finding N if $\log N = 2.3510$

Here, characteristic = 2 and
mantissa = 0.3510

Using Eq. 2.4, the exponent term $= 10^2$

Using Eq. 2.5, the coefficient term = antilog 0.3510
= 2.244

Hence $N = 2.244 \times 10^2 = 224.4$

Example 6

Finding N, if $\log N = 0.3510$

This is similar to previous example except that '0' is the characteristic.

Hence N $=2.244 \times 10^0$

$=2.244$ [since $10^0 = 1$]

ii) When x is negative

When x is negative, use the following steps for finding N, as per Eq. 2.3.

Note that characteristic may be either positive or negative; the mantissa is always positive.

i) The negative number is shown as the sum of a negative integer and a positive fraction.

ii) The negative integer is considered to be the characteristic (or a number having a bar above) and is to be converted into the exponent term using Eq. 2.4. **Note that you get a negative exponent for 10 in this case.**

iii) The positive fraction is equal to the mantissa and is to be converted into the coefficient term by looking for the antilogarithms. For this, you use Eq. 2.5.

iv) The anwer is obtained by multiplying the coefficient term and the exponent term as given in Eq. 2.6.

Use the following examples to understand these steps :

Example 7

Finding N, if $\log N = -4.5000$

We have to find antilog (– 4.5000)

Step (i) : $\log N = -5 + 0.5000$ (or $\bar{5}.5000$)

Step (ii) : characteristic $= -5$

Using Eq. 2.4, exponent term $= 10^{-5}$

Step (iii) : Mantissa $= 0.5000$

Using Eq. 2.5, coefficient term $=$ antilog (0.5000)

$= 3.162$

Step (iv) : Using Eq. 2.6, N = Coefficient Term × exponent term

$N = 3.162 \times 10^{-5}$

In other words, $10^{-4.5000} =$ antilog $(-4.5000) = 3.162 \times 10^{-5}$

Example 8

Finding N, if $\log N = -0.3260$

Step (i) : $\log N = -1 + 0.6740$ (or $\bar{1}.6740$)

Step (ii) : characteristic $= -1$;

Hence, exponent term $= 10^{-1}$

Step (iii) : Mantissa = 0.6740

Hence, coefficient term = antilog 0.6740 = 4.721

Step (iv) : $N = 4.721 \times 10^{-1} = 0.4721$

In other words, $10^{-0.3260} = 0.4721$

Many a times, we have to find the square root, cube root etc. of a number. Now let us study the method of finding a specified root of a number.

Finding the roots using logarithms

To find the specified root of a number using logarithms, do as in the examples discussed below for two different cases.

Finding the specified root of a number greater than 1

Example 9

Find $44300^{1/3}$

$$44300^{1/3} = \text{antilog}\ (\log 44300^{1/3})$$

First find $\log 44300^{1/3}$

$\log 44300^{1/3}$

$= 1/3 \log 44300$ (using rule (i) of Table 2.7)

$= 1/3\ (4.6464)$ (Go to the next step by doing ordinary division)

$= 1.5488$

For finding the root, we use the principle that,
antilog ($\log N$) $= N$

From the above log value, find the antilog value as stated in the previous examples.

antilog (1.5488) = 35.38

Therefore $44300^{1/3}$

$= \text{antilog}\ (\log 44300^{1/3})$

$= 35.38$

Finding the specified root of a positive fraction

Example 10

Find $(0.000004000)^{1/3}$

When the given root of a positive fraction is to be found out, first rewrite the problem using scientific notation.

$$(0.000004000)^{1/3} = (4.000 \times 10^{-6})^{1/3}$$

While taking cube root, we should see whether the exponent in the scientific notation is exactly divisible by 3. In the present case, the exponent (– 6) is exactly divisible 3. In such cases we proceed as follows :

$$(4.000 \times 10^{-6})^{1/3} = \text{antilog}\ (\log\ (4.000 \times 10^{-6})^{1/3})$$

Step (i) : Find the log value of the number in scientific notation.
$\log\ (4.000 \times 10^{-6})^{1/3}$

$=1/3\ [\log 4.000 + \log 10^{-6}]$

$=1/3\ [\log 4.000 - 6 \log 10]$

$=1/3\ [0.6021 - (6 \times 1)]$ [since log 10 = 1]

$=0.2007 - 2$

Step (ii) : Find the antilog value for the answer obtained above using the principles stated previously.

In this section, we have explained the use of logarithms and antilogarithms during calculations. It is preferable to maintain significant figures also during calculations. This aspect will be discussed in Sec. 2.4.

Characteristic $= -2$

Hence, exponent $= 10^{-2}$

mantissa $= 0.2007$

Hence, coefficient term = antilog 0.2007

$= 1.588$

Hence, the answer should be 1.588×10^{-2}

i.e. $(0.000004000)^{1/3} = (4.000 \times 10^{-6})^{1/3}$

$=$ antilog $(\log 4.000 \times 10^{-6})^{1/3}$

$= 1.588 \times 10^{-2}$

Example 11

- Find $(0.0004600)^{1/3}$

$(0.0004600)^{1/3} = (4.600 \times 10^{-4})^{1/3}$

In this case, the exponent term (– 4) is not exactly divisible by 3. In such cases, it is better to convert the exponent term into the nearest lower number that is exactly divisible by 3. In the above example, the exponent term is converted from 10^{-4} to 10^{-6}, since –6 is the nearest number that is lower than –4 and is exactly divisible by 3.

$(4.600 \times 10^{-4})^{1/3} = [460.0 \times 10^{-6}]^{1/3}$

$=$ antilog $[1/3\ (\log 460.0 \times 10^{-6})]$

$=$ antilog $[(1/3 \times 2.6628) + (1/3 \times (-6))]$

$=$ antilog $[0.8876 - 2]$

Characteristic $= -2$ and so, exponent term $= 10^{-2}$

Mantissa $= 0.8876$ and so, coefficient term $= 7.720$

Hence antilog $[0.8876 - 2] = 7.720 \times 10^{-2}$

i.e., $(4.600 \times 10^{-4})^{1/3}$

$=$ antilog $(\log (4.600 \times 10^{-4})^{1/3})$

$= 7.720 \times 10^{-2}$

In this section, we saw the use of some mathematical operations, logarithms and antilogarithms. We must use them in our calculations subject to the following condition:

"The accuracy in the final result in terms of number of digits should be in keeping with the accuracy of the measurements made during the experiment".

To understand the importance of this principle, we must understand the concept of significant figures. This is dealt with in the next section.

In the previous examples, you studied the methods for finding out the cube root. In the following SAQ, you are asked to find out the square root. Try to work out this.

SAQ 6

The solubility product (K_{sp}) of manganous sulphide is given by the formula,

$$K_{sp} = S^2$$

You shall study the method of finding K_{sp} in Unit 9 of Block 3

where S is the solubility of manganous sulphide (in molarity units) in water.

If K_{sp} for manganous sulphide is 3.000×10^{-13}, find its solubility in mol dm^{-3} units. (Note that is a convention to express K_{sp} as a dimensionless number. You take square foot of the given K_{sp} value, which will give S in mol dm^{-3} units.)

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2.4 SIGNIFICANT FIGURES

In Sec. 2.2, we discussed the units of physical quantities. Let us now focus our attention on the magnitude of physical quantities. Whenever we try to make any measurement, we are not certain about the actual value. Errors may creep in due to many reasons. Many a times, the calibration just as in a burette or in a graduated pipette may not be exact. Even the conditions of measurement may vary. For example, warmth expands a scale (ruler) by constant use, or it may get shortened due to rubbing against surfaces. Also, we are limited by the degree of accuracy to which our eyes can read the scales. Finally, our work is always subject to personal error. Since our measurements are uncertain, our report of the measurements taken from experiments should reflect only what we are reasonably sure of. Suppose that an analysis involves a number of measurements. Of these measurements, the one which involves the least accuracy is called the **limiting measurement.** The final calculation would be meaningful if it reflects the accuracy of the limiting measurement. In other words, the final result should not be more accurate than the limiting measurement.

For example in an experiment involving the calculation of molarity of hydrochloric acid using standard sodium carbonate solution, the following two measurements are involved.

Accuracy is the degree of agreement between the measured value and the theoretical value. Accuracy relates to the reliability of the results.

Precision is defined as the degree of agreement between repeated measurements. Precision relates to the **reproducibility** of the results. Precision does not assure accuracy. An example is finding the mass of a substance repeatedly wherein one of the weights used is in error. Same error occurs in each measurement and the answer would be the same during repeated experiments, but still is not exact. That is, the result has precision but not accuracy.

Accuracy in the expression of experimental results should be in keeping with the accuracy in the performance of the experiment. Maintenance of significant figures during calculation helps in avoiding the hyprocrisy of expressing the result which seems to be more accurate than the performance of the experiment!

(i) finding the mass of solid sodium carbonate in an analytical balance accurate to four **decimals;** this is followed by dissolving it in water and making up to a known volume to prepare a standard solution of sodium carbonate.

(ii) finding the titre value of standard sodium carbonate solution for reaction with a known volume of hydrochloric acid; the titre value is known to **one decimal only.**

Of the two measurements involved, the titre value (running for one decimal) has less accuracy than the mass weighed (running for four decimals); hence titre value represents the limiting measurement. This fact should be borne in mind while calculating the molarity of hydrochloric acid. In order to understand the way of representing the final result in keeping with the accuracy of the limiting measurement, we should understand the concept of significant figures.

2.4.1 Calculation of Significant Figures in a Number

The significant figures can be defined as the number of digits necessary to express the results of the experiments consistent with the precision in measurements. Significant figures include all digits of the number representing measurable divisions and one digit representing an estimated division. The significant figures in a measurement are determined using the following rules.

i) The digits 1 to 9 are all important. So the number, 45, has two significant figures; and, the number, 4.946, has four significant figures.

ii) If zero is placed between two non-zero digits, then it is significant. For example, both 3.0045 and 30045 have five significant figures.

iii) Ir zero is to the right of the decimal point forming the final digit(s), then also it is significant. For example, 42.0, 4.20 and 0.420 all have three significant figures.

iv) Zero is not significant when it is used to mark the position of the decimal point in a number less than one. For example, 0.1235 and 0.0001235 both have only four significant figures. The zero in 0.1235 and all the four zeros in 0.0001235 are used to mark the position of a number less than one; hence, these zero's are not significant.

v) A zero that is used to mark the decimal place in a number greater than one is usually not significant. Specially when the zeros are used as place markers rather than being part of the actual measurement, they are not significant. For example, consider the volume of a liquid measured as 600 cm^3 using a measuring jar. Let us examine this for the purpose of significant figure calculation. It is not possible to determine whether the zeros are used merely to place the decimal point or whether they are a part of the measurement. The accuracy depends on whether the subdivisions in the measuring jar are in terms 100 cm^3 or 10 cm^3. In such large-volume measuring jars, 1 cm^3 subdivisions are not made. In the former case, 600 cm^3, represents a significant figure of one and in the latter case, it is two.

The job is made much easier, if you represent the numbers using the scientific notation. **The significant figure in a number is equal to the total number of digits in the coefficient of scientific notation of that number.** For example the number 30900 has its significant figure value depending on the way the coefficient is represented. See the following three cases.

Case i) : 30900 $=3.09 \times 10^4$; significant figure is 3; the subdivisions used in the measurement are in terms of hundreds.

Case ii) : 30900 $=3.090 \times 10^4$; significant figure is 4; the subdivisions used in the measurement are in terms of tens.

Case iii) : 30900 $=3.0900 \times 10^4$; significant figure is 5; the subdivisions used in the measurement are in terms of units (ones).

We can take yet another example, say 0.003061. Its scientific notation is 3.061×10^{-3}. Obviously, this has four significant figures; note that all the zero's before '3061' are not significant.

vi) **The significant figure calculation arises only for measured quantities of an experiment wherein some uncertainty is possible.** The universal constants (such as gas constant, velocity of light etc.), the quantities obtained by counting and, the quantities arising out of definitions (such as 1 inch =2.54 cm) are considered to be exact. **For these exact quantities, we need not calculate the significant figures.** The exact quantities are assumed to have infinite number (i.e., a very large number) of significant figures. Let us see the following examples to understand the significance of exact numbers.

i) For the relationship,
Volume of a sphere $= \frac{4}{3}\pi\ (\text{radius})^3$,

The significant figures in volume and radius should be the same; 4, 3 and π are considered exact since these are constants and, are assumed to have a large number of significant figures. For example, if the radius is 2.4 cm,

then volume of the sphere $= \frac{4}{3} \times \frac{22}{7} \times (2.4)^3\ \text{cm}^3$

$=58\ \text{cm}^3$ (to two signficant figures)

Table 2.9 : Significant Figures and Scientific Notation

Number (i)	Scientific notation (ii)	Coefficient (iii)	Number of digits in the coefficient (iv)	Number of significant figures in the coefficient (v)	Explanation (vi)
307	3.07×10^2	3.07	3	3	All digits are significant. In each case, the decimal point in the number given in column (i) is understood to be after the last digit.
2325	2.325×10^3	2.325	4	4	
307.00	3.0700×10^2	3.0700	5	5	All zeros after the decimal point are significant (since these succeed nonzero digits).
2325.0	2.3250×10^3	2.3250	5	5	
0.00307	3.07×10^{-3}	3.07	3	3	All zeros after the decimal point but before the first nonzero digit are not significant because they only locate the decimal point.
0.02325	2.325×10^{-2}	2.325	4	4	
30700	3.07×10^4	3.07	3	3	All zeros after the last nonzero digit are considered not significant, unless the accuracy of the measurement is known. As per the accuracy of the measurement, the scientific notation is to be written and significant figures calculated accordingly.
	3.0700×10^4	3.0700	5	5	
232500	2.325×10^5	2.325	4	4	
	2.32500×10^5	2.32500	6	6	

The first nonzero digit
(i) in 0.00307 is 3 and
(ii) in 0.02325 is 2.

The last nonzero digit
(i) in 30700 is 7 and
(ii) in 232500 is 5.

Note that the answer ('58 cm^3') has two significant figures, since the radius ('2.4 cm') has only two significant figures. We are not concerned with the significant figures, of 4, 3 and π (i.e., 22/7), since these are exact quantities and are assumed to have a large number of significant figures.

ii) Sometimes , in an experiment we may have to count the number of ions or species. For example in Unit 4, you shall study the 'drop number method' for determining the surface tension of liquids. In this method, one of the measurements relates to the counting of number of drops of a liquid falling through a narrow tube. The number of drops must be a whole number and could be counted exactly. Hence, we need not calculate the significant figures for the drops, (use this idea in SAQ 11 of this unit and in SAQ 3 of Unit 4).

More examples for significant figure calculation are given in Table 2.9.

Before trying to know about arithmetic operations involving significant figures, work out the following SAQ.

SAQ 7

Determine the significant figures for the following:

(i) 7.336 (ii) 8.30 (iii) 1030 (two possible answers)

(iv) 5.4121 (v) 00.00030

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2.4.2 Addition and Subtraction Maintaining Significant Figures

The thumb rule in maintaining the significant figures during addition and subtraction is given below :

The number of decimal places in the result should be the same as the smallest number of decimal places among the data.

If you follow the steps in the same order as given below, addition and subtraction would be easier during the scientific calculations :

i) Write down the numbers to be added or subtracted one below the other in a spacious way and also find out the calculated value as per addition or subtraction.

ii) Put a circle round the significant digit at the right end of each number; this circle indicates the uncertain or estimated figure.

iii) At the top of the numbers, give the column number from right to left in Roman numerals.

iv) For each of the data, locate the column number containing the uncertain or estimated figure. Among the column numbers containing uncertain figures, the highest is noted.

v) The final answer must contain digits only upto this highest column.

Example 12

To illustrate the use of the above rules during addition, an example is given in Table 2.10. This example concerns the following addition :

5.311 +28.12 +1.5102

Table 2.10 : Addition involving significant figures

	Column numbers from right to left						Column number containing the uncertain figure	Highest column number containing uncertain figure
	VI	V	IV	III	II	I		
		5.	3	1	(1)		II	
	2	8.	1	(2)			III	III
		1.	5	1	0	(2)	I	
Calculated answer	3	4.	9	4	1	2		
Final answer is	34.94							

First nonsignificant digit (it is less than 5 and hence is dropped; for explanation see below).

The answer contains only upto column III from right; it is got by rounding off the first nonsignificant digit (1 in column II).

Note that 28.12 has two decimal places while 5.311 and 1.5102 have three and four decimal places, respectively. Hence, the lowest of decimal places in the given data is two. The answer, 34.94 must have two decimal places only in conformity with the thumb rule stated above.

Another fact to be kept in mind while applying the above rules is that the nonsignificant figures are to be rounded off before discarding them. The following principles are used for purposes of rounding off.

a) If the first nonsignificant digit is less than 5, that digit is dropped as such. For the example discussed in Table 2.10, the first nonsignificant digit is 1 and it is dropped (in fact, 0.0012 is dropped as such).

b) If the first nonsignificant digit is equal to or greater than 5, that digit is dropped and the last significant digit is increased by 1. For example, if 5.316, 28.12 and 1.5102 are added, the calculated answer is 34.9462. Similar to the principles illustrated above, 0.0062 is to be omitted. But since the first nonsignificant digit is 6, the final answer is 34.95, (got by rounding off the last significant digit from 4 to 5).

Example 13

An example for subtraction using significant figures has been given in Table 2.11. The example concerns the following subtraction:

Remember that the steps to be followed are the same for both addition and subtraction.

17.58 – 1.246

Table 2.11 : Subtraction involving significant figures

	Column numbers from right to left V	IV	III	II	I	Column number containing the uncertain figure	Highest column number containing uncertain figure
	1	7.	5	(8)		II	II
(–)		1.	2	4	(6)	I	
Calculated answer is	1	6.	3	3	4 ← nonsignificant digit (it is less than 5 and hence, is dropped).		
Final answer is	16.33						

The answer contains only upto column II from right; it is got by rounding off the nonsignificant digit (4 in column I).

Among the two numbers, 17.58 has two decimal places while 1.246 has three decimal places. Evidently the final answer, 16.33, also has two decimal places.

So far we studied the methods of carrying out addition and subtraction maintaining significant figures. Let us next do multiplication and division maintaining significant figures. Before that try the following SAQs.

SAQ 8

Using the individual atomic weights given below, calculate the formula weight of Ag_2MoO_4 maintaining significant figures

Silver	:	107.870
Molybdenum	:	95.94
Oxygen	:	15.9944

SAQ 9

Carry out the following maintaining the significant figures :

6.37 – 4.675

2.4.3 Multiplication and Division Maintaining Significant Figures

The common steps to be followed in multiplication and division maintaining significant figures are given below. You can verify their application using Table 2.12.

i) For each number involved in the multiplication and division operations, write down the scientific notation and the coefficient.

ii) Find out the significant figure value of each coefficient; identify the lowest among these significant figures.

iii) Do the actual multiplication or division using the scientific notation of the numbers. Reduce the answer to the lowest significant figure obtained in step (ii) above. The thumb rule in maintaining significant figures during multiplication and division operations is as follows :

"A product or quotient will contain as many significant figures as the coefficient of the term with the smallest value for significant figure".

You will be able to understand this much better by seeing how the multiplication (25.72 × 221) and the division (666/0.06000) are done in Table 2.12.

Table 2.12 : Multiplication and Division Maintaining Significant Figures

Problem	Number			Lowest of the significant figures	Calculated Value		Coefficent reduced to lowest of the significant figures as given in (v)	Final answer
	Scientific notation	Coefficient	Significant figure		Normal represen-tation	Scientific notation		
(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)
25.72×221	2.572×10^1	2.572	4	3	5684.12	5.68412×10^3	5.68 (to three significant figures)	5.68×10^3
	2.21×10^2	2.21	3					
666 / 0.06000	6.66×10^2	6.66	3	3	11100	1.11×10^4 or 1.110×10^4 or 1.1100×10^4	1.11 (to three significant figures)	1.11×10^4
	6.000×10^{-2}	6.000	4					

As a test of understanding Table 2.12, work out the following SAQs.

SAQ 10

Carry out the following operations and report the answer with proper significant figures :

i) 19.0 × 20.00

ii) 0.79/1.516

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SAQ 11

In Unit 4, you shall study 'drop number method', using which the following relationship between the surface tension values of two liquids such as, mercury and water (r_{Hg} and r_w), can be compared. To do this, number of drops of mercury and water (n_{Hg} and n_w) in the same volume of each liquid and the densities of the two liquids (d_{Hg} and d_w) must be known.

$$\frac{n_w}{n_{Hg}} = \frac{r_{Hg}}{r_w} \cdot \frac{d_w}{d_{Hg}}$$

Using the following data at 293 K, calculate the significant figures in the final answer for n_w/n_{Hg} (the ratio of the number of drops of water to those of mercury). You shall do the actual calculation in SAQ 3 of Unit 4 of Block 2 of this course.

Don't be afraid on seeing the length of SAQ 11 ! Most of it is meant to give you background information. The actual question is given in bold letters.

$$r_{Hg} = 0.472 \text{ N m}^{-1}$$

$$r_w = 0.07288 \text{ N m}^{-1}$$

$$d_{Hg} = 13.6 \text{ kg dm}^{-3}$$

$$d_w = 1.00 \text{ kg dm}^{-3}$$

Hint : Although n_w and n_{Hg} are exact numbers as per the discussion is Subsec. 2.4.1 of this unit, n_w/n_{Hg} is not an exact number; the significant figures in the left side should be equal to those in right side of the relationship stated above.

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2.4.4 Taking Logarithms and Antilogarithms Maintaining Significant Figures

In changing from logarihms to antilogarithms, and vice versa, the number being operated and the logarithm mantissa have the same number of significant figures. **All zeros in the mantissa are significant.**

Taking logarithms Maintaining significant figures

In Column (vi), rounding off is done only, if the significant figures stated in (iv) are less than four.

Any number having more than four digits, should be rounded off to four digits and logarithm should be taken. Any number with less than four digits should be added required number of zero's for the purpose of using four figure logarithms. But the significant figures in the number and those of mantissa should match as shown in the examples below. For this purpose, rounding off procedure is used, wherever required. Go through the examples in Table 2.13.

Table 2.13 : Calculation of Logarithms Maintaining Significant Figures

Example number	Problem	Coefficient value	Number of significant figures	Mantissa: As per four figure logarithms	Mantissa: Rounded off as per column (iv)	Characteristic	Final answer (viii) [(vi) + (vii)]
(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
1	$\log 2.750\times10^{-3}$	2.750	four	0.4393	0.4393 (to four significant figures)	–3	$\log 2.750\times10^{-3}$ =–2.5607
2	$\log 2.75\times10^{-3}$	2.75	three	0.4393	0.439 (to three significant figures)	–3	$\log 2.75\times10^{-3}$ =– 2.561
3	$\log 2.0\times10^{3}$	2.0	two	0.3010	0.30 (to two significant figures)	3	$\log 2.0\times10^{3}$ =3.30

From the above examples, you can see that the mantissa is rounded off to the same number of significant figures as those in the coefficient of the given quantity in scientific notation. Final answer is expressed with one more significant figure (which is due to the characteristic). Thus, 2.750 in Example (1) of Table 2.13 has four significant figures, whereas the answer, –2.5607 has five significant figures; four due to mantissa and one due to the characteristic.

Taking antilogarihms Maintaining Significant Figures

As said for logarithms, the significant figures in the mantissa and the coefficient in the scientific notation must match. Necessary rounding off is done with four figure antilogarithms. Study the following examples in Table 2.14. All problems follow the equation,

$$\log N = x$$

In each case, x is given and N is to be found out using the relationship, N =antilog x. The x value is written in a rearranged form in column (iii) to show the characteristic and mantissa parts separately.

Table 2.14 : Calculation of Antilogarithms Maintaining Significant Figures

Example Number (i)	x (ii)	Rearranged x (iii)	Mantissa (with proper significant figures) (iv)	Coefficient = antilog (mantissa) (v)	Characteristic (vi)	Exponent term (vii)	Answer in scientific notation: N=antilog x (viii)
1.	–4.7166	–5 +0.2834	0.2834 (four singnificant figures)	1.921 (four significant figures)	–5	10^{-5}	antilog (–4.7166) $=1.921 \times 10^{-5}$
2.	–2.70	–3 +0.30	0.30 (two significant figures)	2.0 (1.995 rounded to two significant figures)	–3	10^{-3}	antilog (–2.70) $=2.0 \times 10^{-3}$
3.	6.5100	6 +0.5100	0.5100 (four significant figures)	3.236 (four significant figures)	6	10^{6}	antilog (6.5100) $=3.236 \times 10^{6}$
4.	6.510	6 +0.510	0.510 (three significant figures)	3.24 (3.236 rounded to three significant figures)	6	10^{6}	antilog (6.510) $=3.24 \times 10^{6}$

In the next section, we shall discuss the method of maintaining the laboraory note book.

Using the above ideas, work out the following SAQ.

SAQ 12

Using the relationship. pH =–log [H^+]

where [H^+] is in molarity, calculate [H^+] of a solution for which pH is 4.70, maintaining the singificant figures. Express the answer in molarity.

Note: During calculation, the equation, pH =– log [H^+] should be considered as the expression, pH=– log [H^+]/M where M is the symbol of molarity unit. To understand this, see subsec. 2.2.4.

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2.5 LABORATORY NOTE BOOK

It is essential to keep a proper record of the work that has been done. The record should reflect all the observations at various stages of the experiment. The observations prove helpful in correct interpretation of an experimental result.

While preparing a laboratory note book, the following important features may be kept in mind.

- The laboratory note book is a complete record of all operations. Date, time, the number and the title of each experiment must be entered regularly.
- Record all observations and data in the note book at the time they are obtained. Never use scraps of paper for noting particulars like masses of substances weighed, melting points, titre values etc. They might get lost or mixed up.
- The record should be clearly written and well organised. On reading it, one should be able to understand what has been done. It may not be necessary to copy out the exact procedure, since this is given in your laboratory manual. Detailed calculations are to be shown. Results should be summarised, conclusions drawn for each experiment and explanation provided, if the results vary from those expected. **Certain marks have been allotted for maintaining a good laboratory note book.**

Some of the important points to remember in maintaining a laboratory note book are given below:

From a stationery shop, buy your record note book and graph sheets.

- A bound note book should be used for laboratory record. You may use a laboratory note book in which one side has ruled pages and other side is unruled.
- All entries must be made in ink. If you commit a mistake, it should be crossed and correct entry should be made.
- The first few pages in the note book should be left for making a list of contents.
- Graphs drawn should be attached to the laboratory note book.

2.6 TABULATION OF DATA AND PLOTTING OF GRAPHS

While doing calculations, unit of the physical quantities must be mentioned. Tabular columns must have relevant titles. While tabulating the data, the physical quantities should be represented as dimensionless quantities by dividing the physical quantities by appropriate units. Thus, in the titration table given in Sec. 1.7 of Unit 1, the volume of the solution is divided by cm^3 units to facilitate the entries as mere numbers. In the examples given in Sec. 1.6 and 1.7 of Unit 1, we showed how to enter the data for weighing and calculation of molarity.

Plotting a Graph

Often experimental data can be analyzed by plotting a graph. While plotting a curve, x– and y– coordinates must be represented as dimensionless quantities by dividing the physical quantities by appropriate units. Proper scales should be chosen. The graph should be given a suitable title. In many cases, we come across straight line plots. You shall come across straight line plots in Units 11, 12, 13, 15 and 16. The straight line plots help us in confirming a linear relationship between the quantities plotted. For this, we have to calculate the slope of a straight line plot. If the slope is positive, there is a direct proportionality between the two quantities; if the slope is negative, there is an inverse relationship between the two. To find the slope of a straight line, select two points (x_1, y_1) and (x_2, y_2) on the straight line and apply the formula:

A linear relationship is said to exist if increase in y *is proportional to increase or decrease in* x (but not to increase or decrease in $x^2, x^3, x^{-2}, x^{-3}, e^x$, etc. values).

A straight line curve obeys the equation,

$$y = mx + c$$

where m and c are the slope and the y – intercept, respectively.

$$\text{Slope} = \frac{(y_2 - y_1)}{(x_2 - x_1)} \qquad \ldots (2.7)$$

Example 14

To understand the above, let us discuss an example. In this example, the graphical method of calculation of the first order rate constant for the hydrolysis of benzene diazonium chloride is illustrated. Benzene diazonium chloride gets hydrolysed as follows:

$$C_6H_5N_2Cl \longrightarrow C_6H_5OH + N_2 + HCl$$

The volumes of nitrogen liberated at various time intervals (t) are denoted by V_t while the volume of nitrogen liberated at infinite time is denoted by V_∞. The first order rate constant, k, is given by the equation.

$$\log (V_\infty - V_t) = \log V_\infty - \frac{k}{2.303} t \qquad \ldots (2.8)$$

This is of the form, $y = c + mx$, which is an equation for a straight line.

Comparing these two equations,

$$\text{Slope} = m = -\frac{k}{2.303}$$

$$k = -2.303 \times \text{slope} \qquad \ldots (2.10)$$

In other words, from the slope of $\log (V_\infty - V_t)$ against t plot, k can be obtained.

We now state in this example,

- the way of representing the data for plotting a curve,
- the actual plot and
- the way of calculating the slope using Eq. 2.7.

Data for the hydrolysis of benzene diazonium chloride

t/s	0	1500	3000	4500
$(V_\infty - V_t)$/cm^3	81.0	74.6	68.9	63.4
$\log (V_\infty - V_t)$/cm^3	1.908	1.873	1.838	1.802

During calculation, we write the left hand side of Eq. 2.8 as $\log (V_\infty - V_t)/\text{cm}^3$, in order to represent it as a dimensionless quantity. In order to understand this, see subsec. 2.2.4.

Using these data, $\log (V_\infty - V_t)$ against t plot is made as shown in Fig. 2.2.

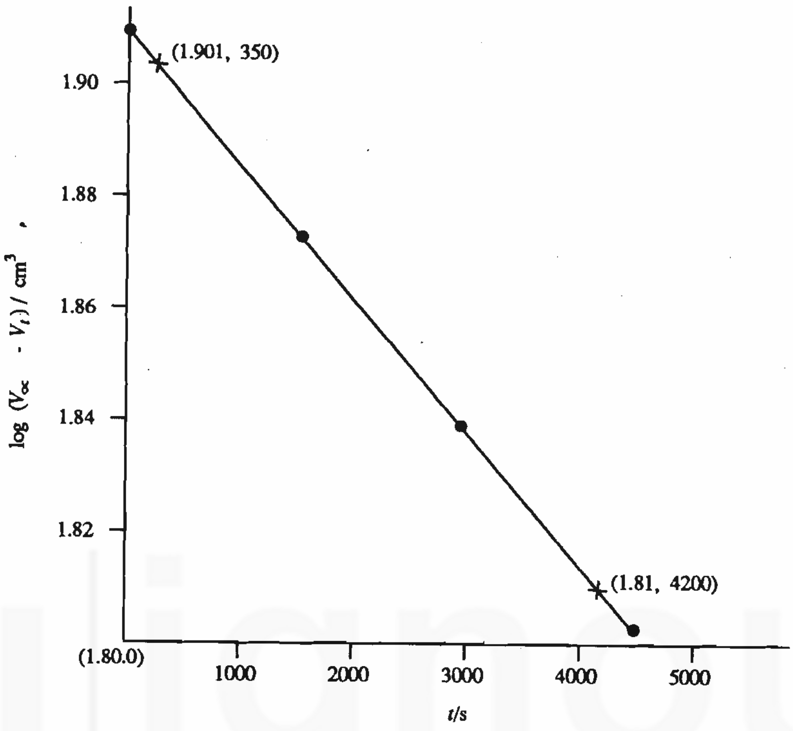

Fig. 2.2 : log $(V_\infty - V_t)$ against t plot

For calculating the slope, choose two points on the straight line and indicate them by '×' mark. Find the x and y coordinates corresponding to these two points. Substitute these values in Eq. 2.7 and calculate the slope of the straight line. This is illustrated below:

The unit of slope

$$= \frac{\text{Unit of } y \text{ coordinate}}{\text{Unit of } x \text{ coordinate}}$$

$$= \frac{\text{Unit of } \log(V_\infty - V_t)/\text{cm}^3}{\text{Unit of } t}$$

$$= \frac{1}{\text{s}} \text{ or s}^{-1}$$

Using Eq. 2.7, slope $= \dfrac{(1.81 - 1.901)}{(4200 - 350)\text{ s}}$

$= -2.36 \times 10^{-5} \text{ s}^{-1}$

Using Eq. 2.10, k $= -2.303 \times \text{slope}$

$= -2.303 \times (-2.36 \times 10^{-5} \text{ s}^{-1})$

$= 5.44 \times 10^{-5} \text{ s}^{-1}$

While drawing a straight line, sometimes all the points may not fall on a line. In such cases, draw the straight line in such a way that (i) it passes through as many points as possible or (ii) the points are scattered symmetrically around the straight line.

Test Value : The value which is to be determined using an experiment.

Sometimes it may be necessary to find the x-coordinate, corresponding to a y-coordinate and vice versa, using the straight line plot as such, Fig. 2.3. This is called **interpolation**. In this case, the test value of x (or y) falls in between the extreme limits of x coordinates (or y coordinates) of points used for plotting the graph. The interpolation of a value is done **within** the experimentally tested range of linear relationship.

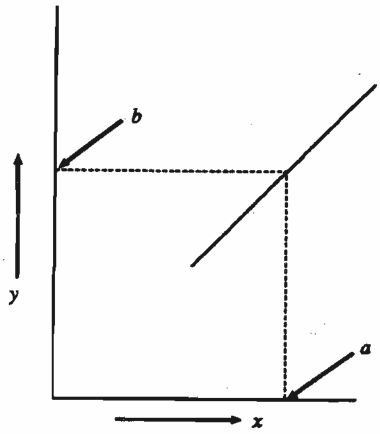

Fig. 2.3 : Interpolation method; *a* and *b* are the values of *x* and *y* coordinates for the test case. If *a* (or *b*) is found out by experiment. then *b* (or *a*) can be known by drawing dotted lines intercepting the straight line as shown in the figure.

To cite an example, we can use interpolation method in colorimetric experiment to find the concentration of a given solution from its absorbance value (or meter response) using the absorbance (or meter response) against concentration plot. We shall study this in Sec. 3.2 of Unit 3.

In certain situations, we may have to extend a straight line graph to obtain *x*– (or *y*– coordinate) from the known *y*– (or *x*–coordinate). This is called extrapolation. Extrapolation is not always reliable because the testing of a quantity is done beyond the experimentally tested limits of linear relationship. Any deviation from linear relationship will result in yielding an inaccurate result. For example, Beer-Lambert law, which is the guiding principle for colorimetry, holds over limited concentration ranges. Extrapolation is not allowed in this case.

2.7 SUMMARY

In this Unit, we discussed the SI units of basic and derived physical quantities. We explained the method of representing a number using scientific notation . We defined the term, significant figure. We explained the ways of maintaining significant figures while carrying out calculations. We discussed some features regarding the recording of observations, tabulation of data and plotting graphs.

2.8 ANSWERS

Self Assessment Questions

1) Units of k = units of (reaction rate/ [reactant]^2)

$$= M\,s^{-1}/M^2 = M^{-1}\,s^{-1}$$

where $M = mol\ dm^{-3}$

2) Units of kinetic energy = Unit of (mass × (velocity)^2)

$$= kg\,m^2\,s^{-2}$$

$$= J$$

3) (a) nm (b) ps (c) kPa

4) 0.015×10^{-4} S $= 1.5 \times 10^{-6}$ S

$= 1.5\ \mu$S

5) Units of R = J mol^{-1} K^{-1}

= J/mol K

6) $S = (K_{sp})^{1/2}$

$= (3.000 \times 10^{-13})^{1/2}$ mol dm^{-3}

$= (30.00 \times 10^{-14})^{1/2}$ mol dm^{-3}

$= 5.476 \times 10^{-7}$ mol dm^{-3}

7) (i) 4 (ii) 3 (iii) 4 (in 1.030×10^3) and 3 (in 1.03×10^3) (iv) 5 (v) 2 (all the five zeros before 3 are nonsignificant whereas zero after 3 is significant).

8)

	215.740	(2 × Atomic weight of Ag)
	95.94	(1 × Atomic weight of Mo)
	63.9776	(4 × Atomic weight of oxygen)
Calculated answer	375.6576	

Final answer = 375.66 (rounded to two decimal places since the data 95.94, which has the least number of decimals, has two places.)

9)

	6.37
	– 4.675
Calculated answer	1.695

Final answer = 1.70 (rounded to two decimal places since 6.37 has two decimal places while 4.675 has three decimal places).

10) i) 3.80×10^2 (to three significant figures)
ii) 5.2×10^{-1} (to two significant figures)

11) Of the various terms in the given relationship, except r_w, which has four significant figures, all the others (r_{Hg}, d_{Hg} and d_w) have only three significant figures. Hence the final answer also should have three significant figures.

12) pH = –log [H$^+$]/M = 4.70

log [H$^+$]/M = – 4.70

= – 5 + 0.30

Since mantissa (0.30) has two significant figures, the coefficient also has two significant figures. Coefficient term = antilog (0.30)

= 2.0

Exponent term = 10^{-5}

∴ [H$^+$] = Coefficient term × exponent term

$= 2.0 \times 10^{-5}$ M

Logarithms

	0	1	2	3	4	5	6	7	8	9	differences 1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
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	6571	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
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

	0	1	2	3	4	5	6	7	8	9	differences 1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9653	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	9991	9996	0	1	1	2	2	3	3	3	4

Antilogarithms

	0	1	2	3	4	5	6	7	8	9	differences								
											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	1302	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
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.48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	4	4	5	6	6
.49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	4	4	5	6	6

	0	1	2	3	4	5	6	7	8	9	differences 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
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.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
.62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5	6	7	8	9
.63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
.64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
.66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	9	10
.67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
.69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6	7	8	9	10
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.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
.72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6	7	9	10	11
.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6	8	9	10	11
.74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6	8	9	10	12
.75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7	8	9	10	12
.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	9	11	12
.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7	8	10	11	12
.78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7	8	10	11	13
.79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7	9	10	11	13
.80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7	9	10	12	13
.81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8	9	11	12	14
.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	12	14
.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8	9	11	13	14
.84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
.85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8	10	12	13	15
.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	12	13	15
.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9	10	12	14	16
.88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9	11	12	14	16
.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9	11	13	14	16
.90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9	11	13	15	17
.91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9	11	13	15	17
.92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	12	14	15	17
.93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10	12	14	16	18
.94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	12	14	16	18
.95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10	12	15	17	19
.96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11	13	15	17	19
.97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
.98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11	13	16	18	20
.99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20