PHYSICAL PHARMACY I

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1st level

2020

Text book: Alfred Martin

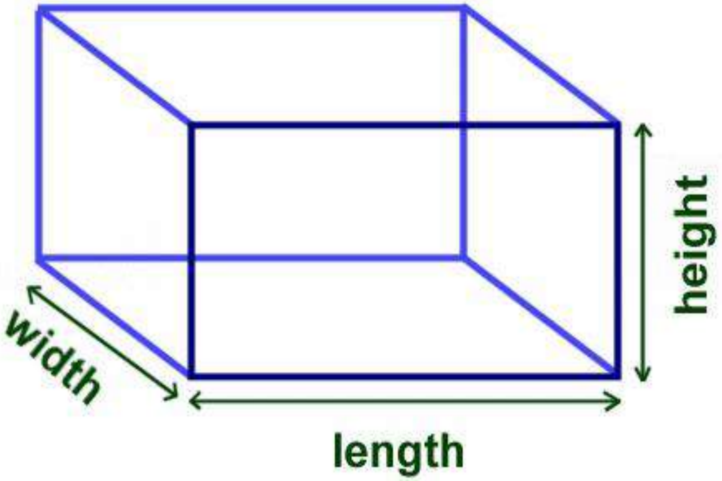
Contents:

- Introduction
- States of Matter
- Physical Properties of Drug Molecules
- Solutions of Nonelectrolytes
- Solutions of Electrolytes
- Buffered and Isotonic Solutions
- Solubility and Distribution Phenomena

INTRODUCTION
DIMENSIONS AND UNITS

The properties of matter are usually expressed by the use of three **fundamental dimensions:**

1. Length
2. Mass
3. time



Two systems of units:

1. **Metric system (CGS):** the units are the centimeter (cm), the gram (g), and the second (sec)

2. **The International Union of Pure and Applied Chemistry (IUPAC)** has introduced a System International or **SI units**

TABLE 1–1. ***Fundamental Dimensions and Units***

Dimension (Measurable Quantity)	Dimensional Symbol	CGS Unit	SI Unit
Length (*l*)	*L*	Centimeter (cm)	Meter (m)
Mass (*m*)	*M*	Gram (g)	Kilogram (kg)
Time (*t*)	*T*	Second (sec)	Second (s)

Derived quantities or dimensions such as area, density, pressure, and energy are compounded from the three fundamental dimensions

Table 2 showing some common Derived Quantities.

Derived Quantity		S.I. Unit	
Name	Symbol	Name	Symbol
Area	A	metre squared	m^2
Volume	V	metre cubed	m^3
Speed	s	metre/second	m/s
Velocity	*v*	metre/second	m/s
Acceleration	a	metre/second^2	m/s^2
Force	F	newton	$N = kg\ m/s^2$
Energy	E	joule	J = N m
Density	ρ	kilogram/metre cubed	kg/m^3
Moment	T	newton metre	N m
Power	P	watt	W = N m/s
Work	W	joule	J = N m
Momentum	ρ	kilogram metre/second	kg m/s = N s
Pressure	P	pascal	$Pa = N/m^2$

1- Length and Area

Length measures the distance

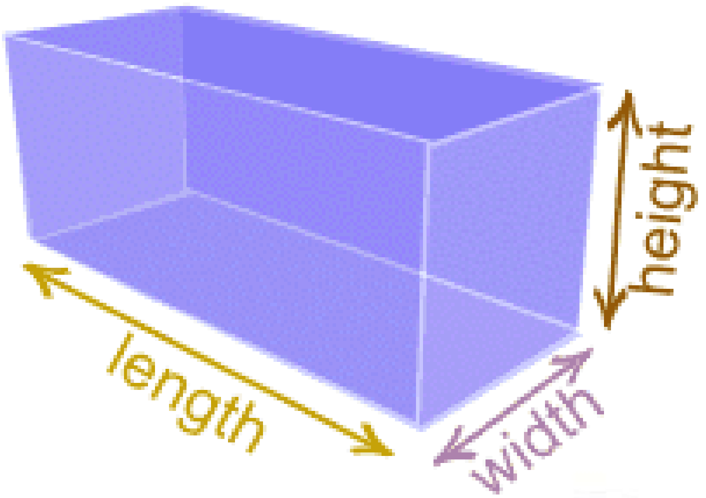
The cgs unit is centimeter (cm)

TABLE 1–2. ***Fractions and Multiples of Units***

Multiple	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

2- Volume

- measurable quantity derived from length
- its cgs unit is 1 cubic centimeter (cc or cm3).



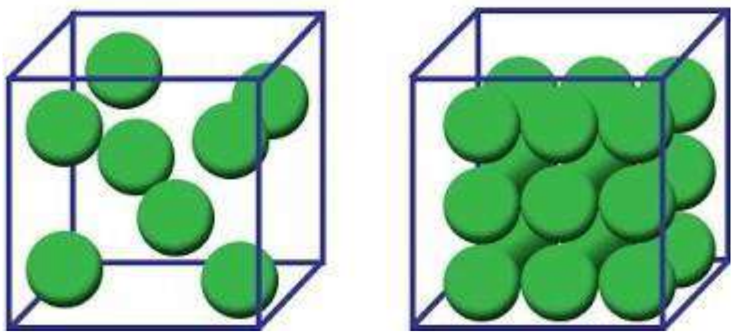
- Liter: original unit. the volume of a 1 kilogram of water at 1 atmosphere pressure and 40 C, and be equivalent to 1000 cm3
- 1 liter actually equals 1000.027 cm3.
- but it is so slight as to be disregarded in general chemical and pharmaceutical practice.

3- Mass

- The practical unit of mass in the cgs system is the **gram** (g), which is one thousandth of a kilogram.
- Mass is often expressed as the weight of a body.

1 kilogram = 1000 grams

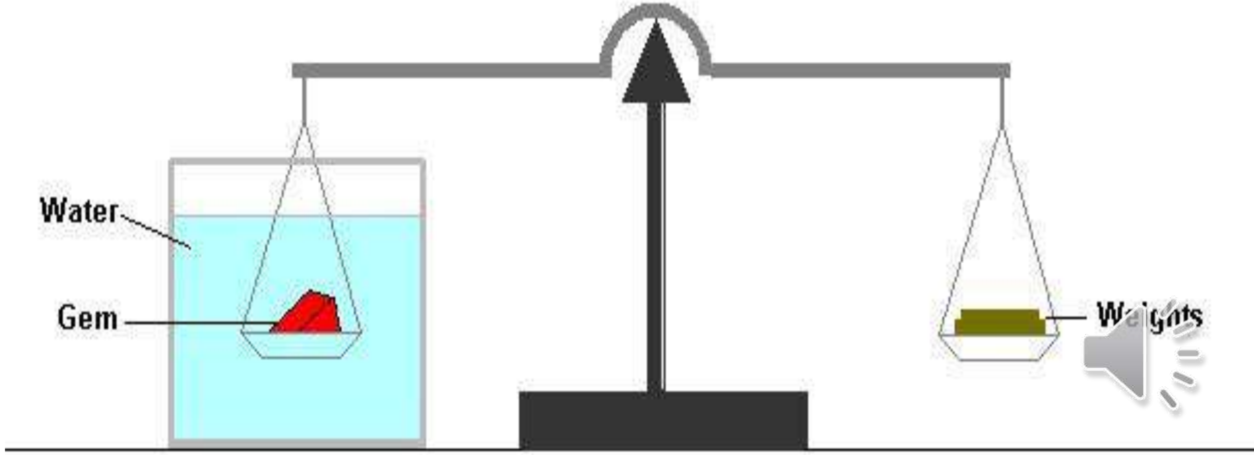
4- Density and Specific Gravity



- Interconverting between mass and volume.
- **Density** is mass per unit volume at a fixed temperature and pressure
- expressed in the cgs system in grams per cubic centimeter (g/cm3)

  and in SI units as Kg/m3
- **Specific Gravity** is the ratio of the density of a substance to the density of water (relative density)

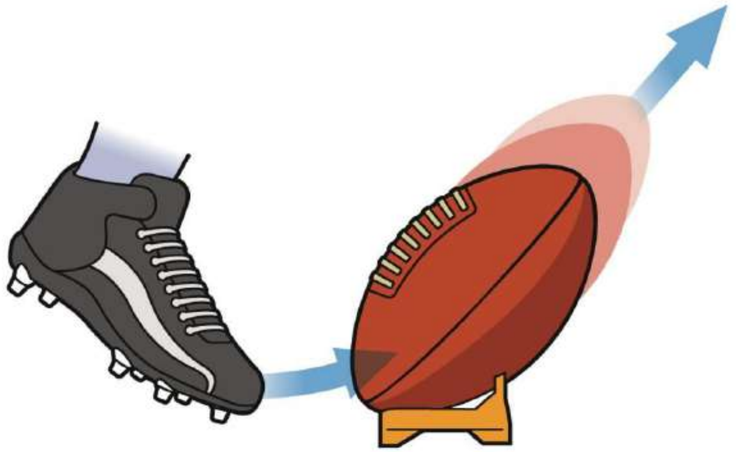
  the ratio of the mass of a substance to the mass of an equal volume of water

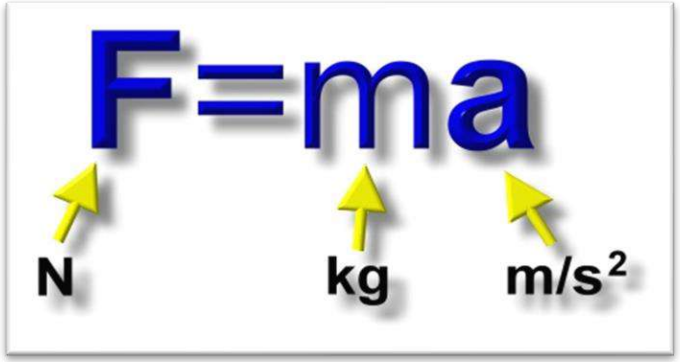


5- Force

a push or pull required to set a body in motion.

Force = Mass x Acceleration

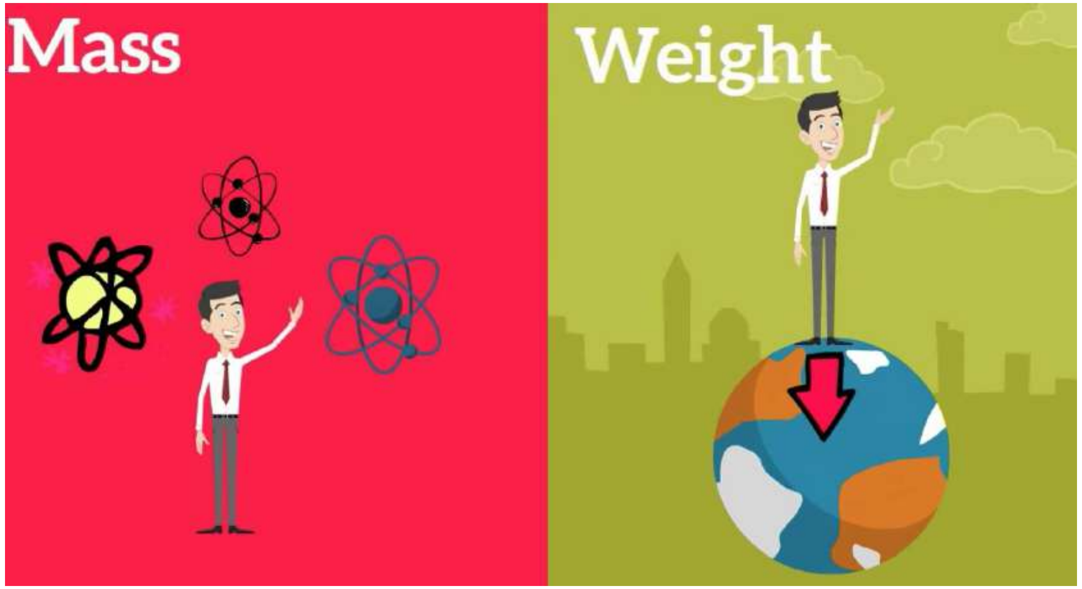




- The SI unit of force is the **newton (N)**, defined as the force that imparts to a mass of **1 kg** an acceleration of **1 m/sec2**
- The cgs unit of force is the **dyne**, defined as the force that imparts to a mass of **1 g** an acceleration of **1 cm/sec2**

$$1N = 10^5 \text{ dyne}$$

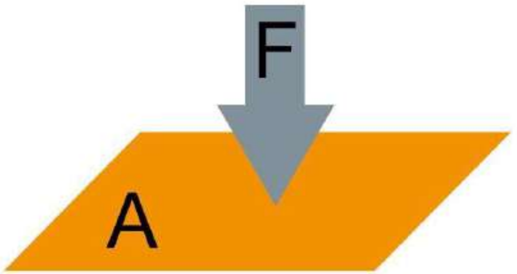
- **Weight** is the force of gravitational attraction that the earth exerts on a body
- it should be expressed properly in force units (dynes) rather than mass units (grams).
- W = m.g
- w = 1 g x 981 cm/sec2
- The weight of a 1 gram mass is 981 g.cm/sec2



6- Pressure

$$Pressure\ (p) = \frac{Force\ (F_n)}{Area(A)}$$

- defined as force per unit area
- the cgs unit is dyne/cm2
- The SI unit is N/m2 (Pascal; Pa)
- Pressure is often given in **atmospheres (at** millimeters of mercury.



- This latter unit is derived from a measurement of the height of a column of mercury in a barometer, which is used. to measure the atmospheric pressure.
- pressure (dyne/cm2) = **p x g x h**

$$= \frac{g}{cm3} * \frac{cm}{sec2} * cm$$

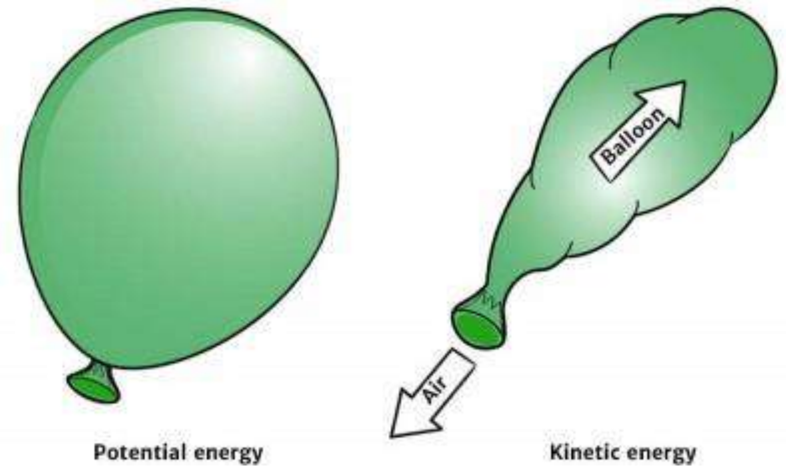
- At sea level, the mean pressure of the atmosphere supports a column of mercury (p = 13.595 g/cm30 76 cm (760 mm) in height
- 1 atm = 1.0133 x 10^6 dyne/cm^2

7- Work and Energy

Energy is defined as the condition of a body that gives it the capacity for doing work.

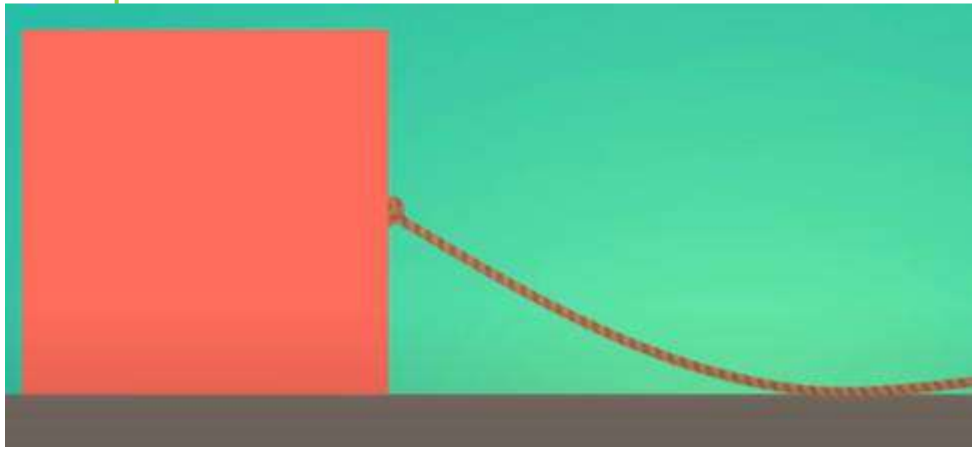
classified as:

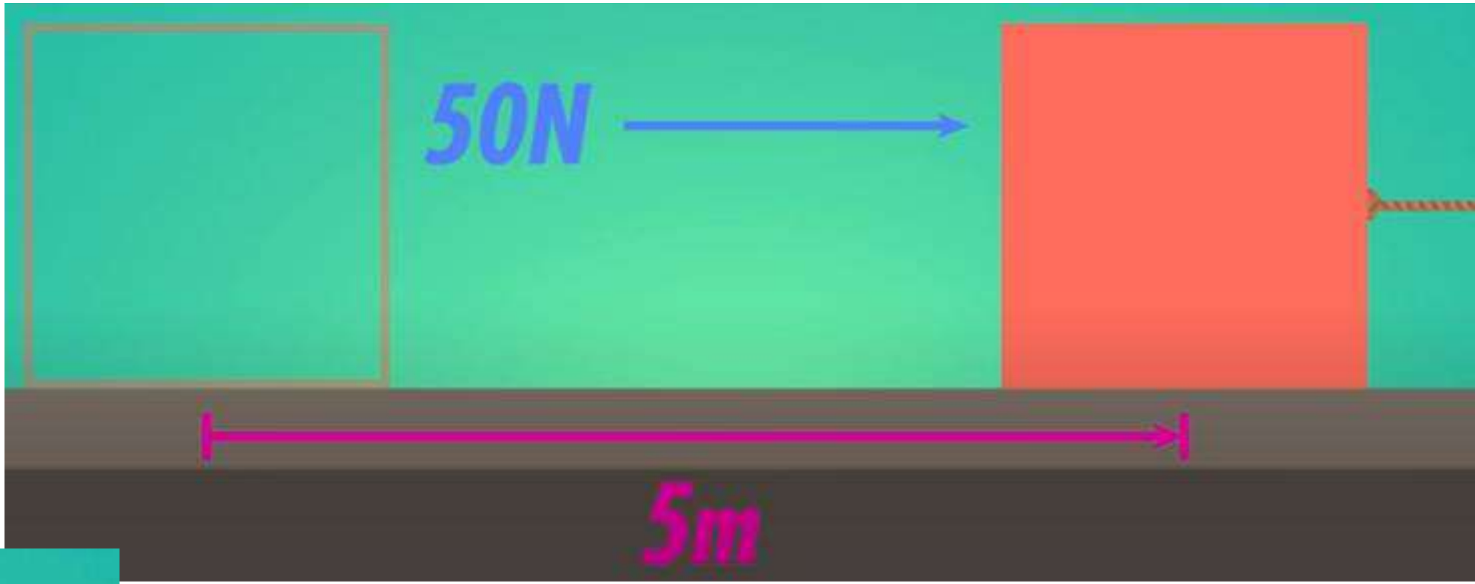
1) kinetic energy
2) potential energy

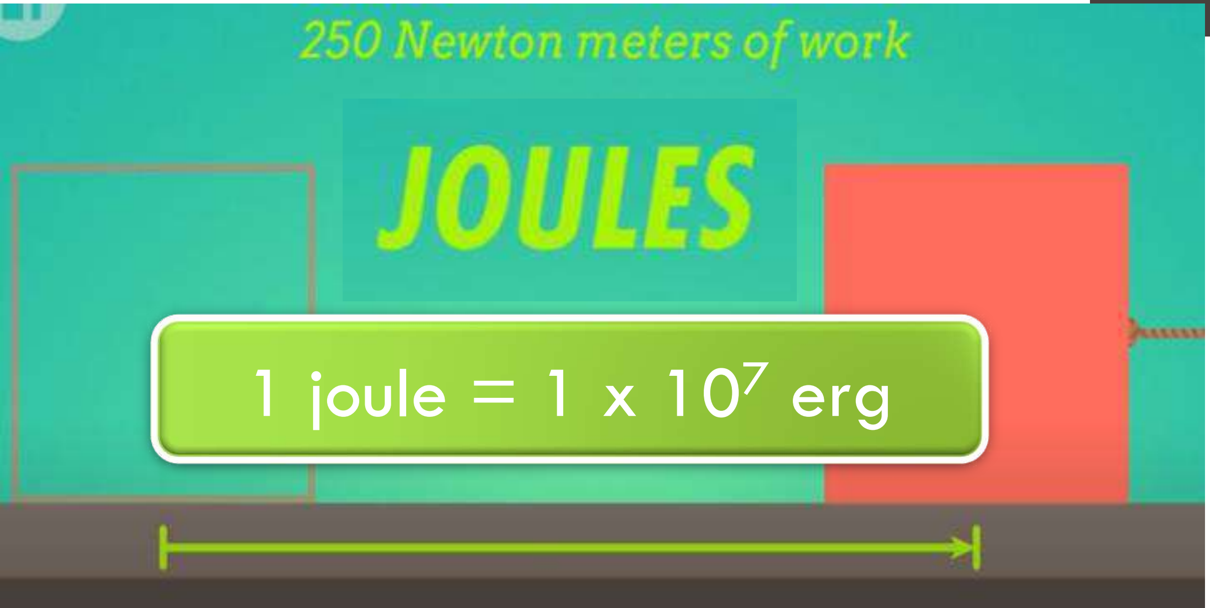


The idea of energy is best approached by way of the mechanical equivalent of energy known as **work** and the thermal equivalent of energy or **heat.**

When a constant force is applied to a body in the direction of its movement, the work done on the body equals the force multiplied by the displacement, and the system undergoes an increase in energy.







- ✓ SI unit: **Joule** (Newten . m)) which is defined as the work done when a force of 1 Newten acts through a distance of 1 m
- ✓ Cgs unit: **erg** (dyne .cm) which is defined as the work done when a force of 1 dyne acts through a distance of 1 cm

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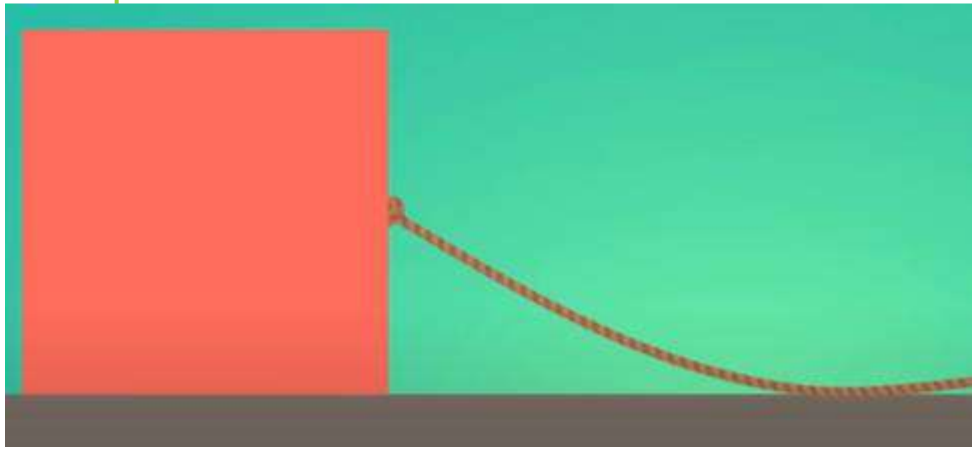
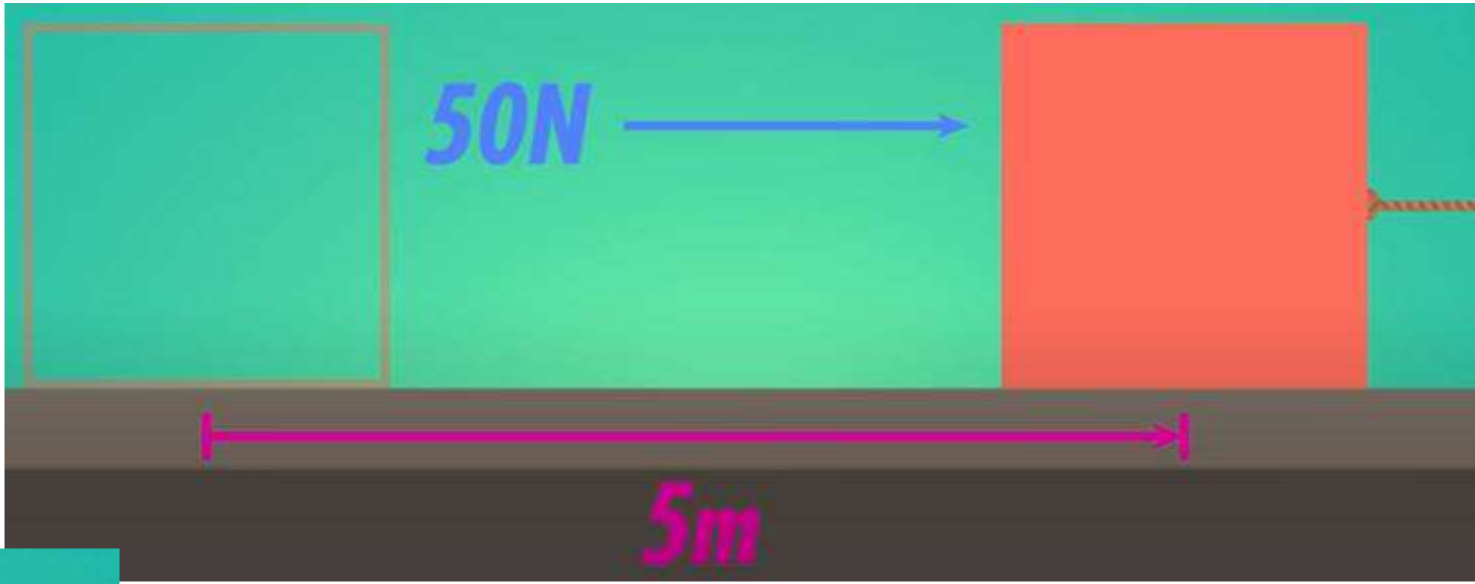
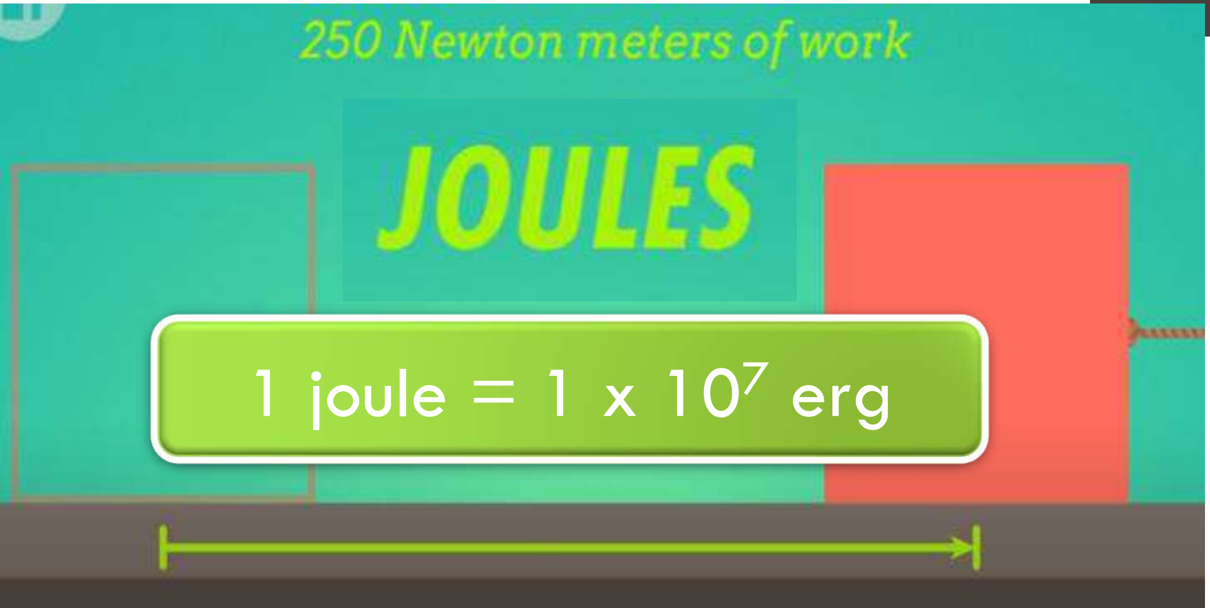






1 joule = 1 x 10^7 erg

- ✓ SI unit: **Joule** (Newten . m)) which is defined as the work done when a force of 1 Newten acts through a distance of 1 m
- ✓ Cgs unit: **erg** (dyne .cm) which is defined as the work done when a force of 1 dyne acts through a distance of 1 cm

Heat and work are equivalent forms of energy and are interchangeable under certain circumstances.

The thermal unit of energy:

cgs unit: **gram calorie** (small calorie).

SI unit: amount of heat necessary to raise the temperature of 1 gram of water from 15° to 16° C.

small calorie = 4.184 joules.

large or kilogram calorie (kcal) = 1000 small calories

8- Temperature

Centigrade and Kelvin scale

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

SOME ELEMENTS OF MATHEMATICS

- **Ratio and proportions** are frequently used in the physical sciences for conversions from one system to another.

Question: How many seconds are there in 1 year?

Conversion Factors:

365 days = 1 year   24 hr = 1 day   60 min = 1 hr   60 sec = 1 min

Rearrange Conversion Factors:

$$\frac{\text{365 days}}{\text{1 year}} = 1 \qquad \frac{\text{24 hr}}{\text{1 day}} = 1 \qquad \frac{\text{60 min}}{\text{1 hr}} = 1 \qquad \frac{\text{60 sec}}{\text{1 min}} = 1$$

Solve (arrange conversion factors so that the units that you do not want cancel out):

$$\frac{365\ \cancel{\text{days}}}{1\ \text{year}} \times \frac{24\ \cancel{\text{hr}}}{1\ \cancel{\text{day}}} \times \frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{hr}}} \times \frac{60\ \text{sec}}{1\ \cancel{\text{min}}}$$

Calculate: Now, plug the numbers carefully into your calculator and the resulting answer is 31,536,000 sec/year.

How many calories are there in 3.00 joules?

1 cal = 4.184 joules

If 1 cal → 4.184 joules

??? → 3.00 joules

$$X = \frac{3.00 \text{ joules} \times 1 \text{ cal}}{4.184 \text{ joules}}$$

$$X = 0.717 \text{ cal}$$

How many gallons are equivalent to 2.0 liters?

1 liter = 1000 ml, 1 pint = 473 mL, 1 gallon = 8 pints

$$X \text{ (in gallons)} = 2.0 \text{ liter} \times \frac{1000 \text{ mL}}{1\ liter} \times \frac{1\ pint}{473\ ml} \times \frac{1\ gallon}{8\ pints}$$

$$X = 0.53 \text{ gallon}$$

Exponents

the powers to which a number is raised

The Rules of Exponents:

$a \times a \times a = a^3$

$a^2 \times a^3 = a^{2+3} = a^5$

$(a^2)^3 = a^2 \times a^2 \times a^2 = a^6$

$\left(\frac{a}{b}\right)^3 = a^3/b^3$

$a^5/a^2 = a^{5-2} = a^3$

$a^5/a^4 = a^{5-4} = a^1 = a$

$a^2/a^4 = a^{2-4} = a^{-2} = \frac{1}{a^2}$

$a^2/a^2 = a^{2-2} = a^0 = 1$

$a^{1/2} = \sqrt{a}$

$a^{1/2} \times a^{1/2} = a^{1/2+1/2} = a^1 = a$

$a^{2/3} = (a^2)^{1/3} = \sqrt[3]{a^2}$

Logarithms

$3^4 = 3 \times 3 \times 3 \times 3 = 81$

$3^4 = 81$

$\log_3 81 = 4$

$3^{\boxed{4}} = 81$

Tow types

- Common logarithm: the base is 10

$\text{Log}_{10}\ 1000 = 3 \rightarrow \text{antilog}\ 3 = 1000$

If $b^x = a \rightarrow \text{Log}_b\ a = x$ [the logarithm to the base (b) of (a) is (x)]

- Natural logarithm: the base is $e = 2.718$ ($\text{Log}_e = \ln$)
- $\ln a = 2.303 \log a$

TABLE 1–5. *Rules of Logarithms*

$$\log ab = \log a + \log b$$

$$\log \frac{1}{a} = \log 1 - \log a = -\log a$$

$$\log \frac{a}{b} = \log a - \log b$$

$$\log a^2 = \log a + \log a = 2 \log a$$

$$\log 1 = 0 \text{ since } 10^0 = 1$$

$$\log \sqrt{a} = \log a^{1/2} = \tfrac{1}{2} \log a$$

$$\log a^{-2} = -2 \log a = 2 \log \frac{1}{a}$$

Variation

- The dependence of one property, the dependent variable y, on the change or alteration of another measurable quantity, the independent variable x, is expressed mathematically as $y \propto x$

$$\frac{y_1}{x_1} = \frac{y_2}{x_2} = \cdots \qquad \frac{y}{x} = \text{constant}$$

General formula: $y = kx$

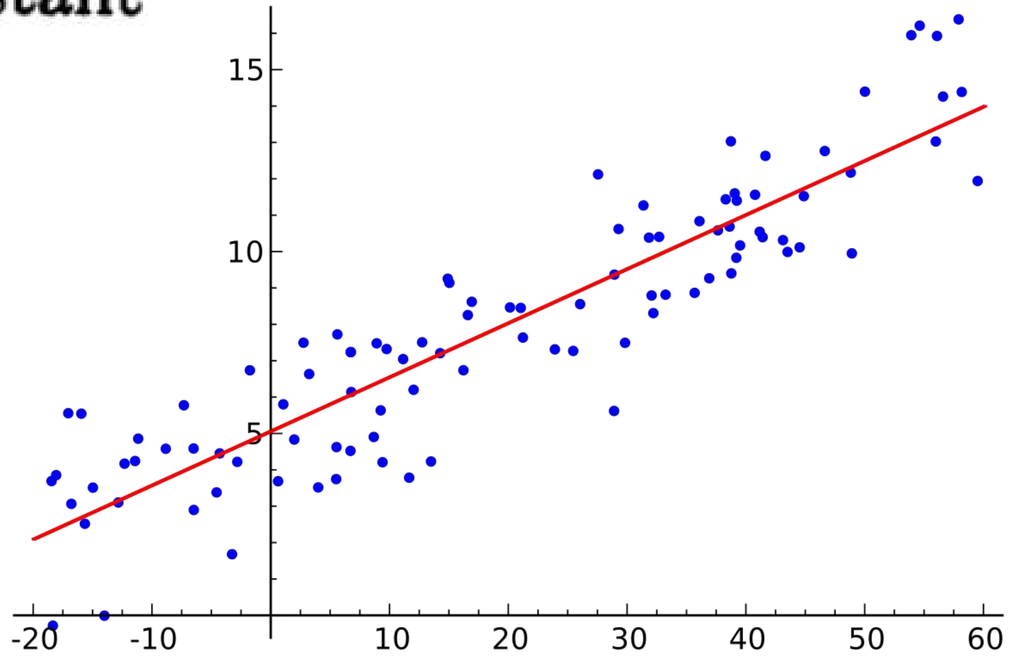


TABLE 1–6. ***Formulas Illustrating the Principle of Variation***

Measurement	Equation	Dependent Variation	Independent Variable	Proportionality Constant
Circumference of a circle	$C = \pi D$	Circumference, C	Diameter, D	$\pi = 3.14159 \ldots$
Density	$M = \rho V$	Mass, M	Volume, V	Density, ρ
Distance of falling body	$s = \frac{1}{2}gt^2$	Distance, s	Time, t^2	Gravity constant, $\frac{1}{2}g$
Freezing point depression	$\Delta T_f = K_f m$	Freezing point depression, ΔT_f	Molality, m	Cryoscopic constant, K_f

- **Graphic Methods**
- collect raw data and put them in the form of a table or graph to better observe the relationship
- observe the relationship more clearly
- and perhaps allows expression of the connection in the form of a mathematical equation
- The procedure of obtaining an empiric equation from a plot of the data is known as **curve fitting**
- The magnitude of the independent variable → horizontal scale → called the X axis
- The dependent variable is measured along the vertical scale or the y axis

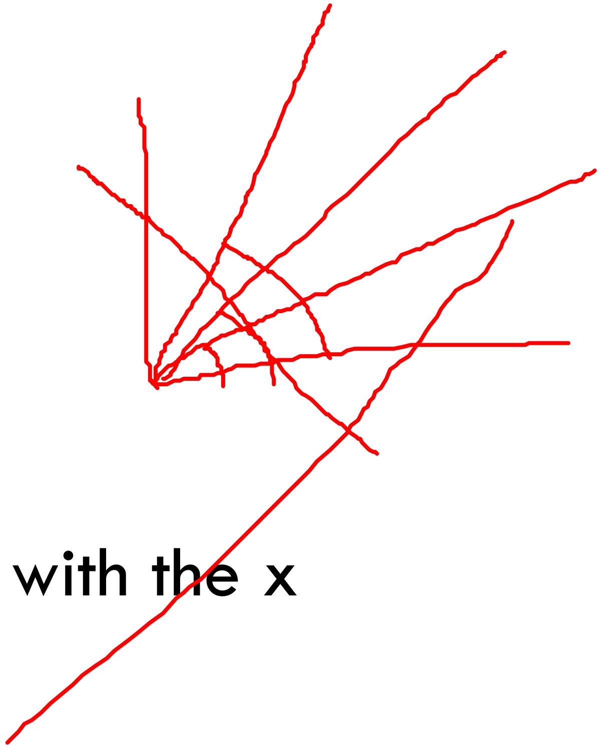
- The simplest relationship between two variables where the variables contain no exponents other than one **(first-degree equation)**, yields a straight line when plotted on rectangular graph paper

$$y = a + bx$$

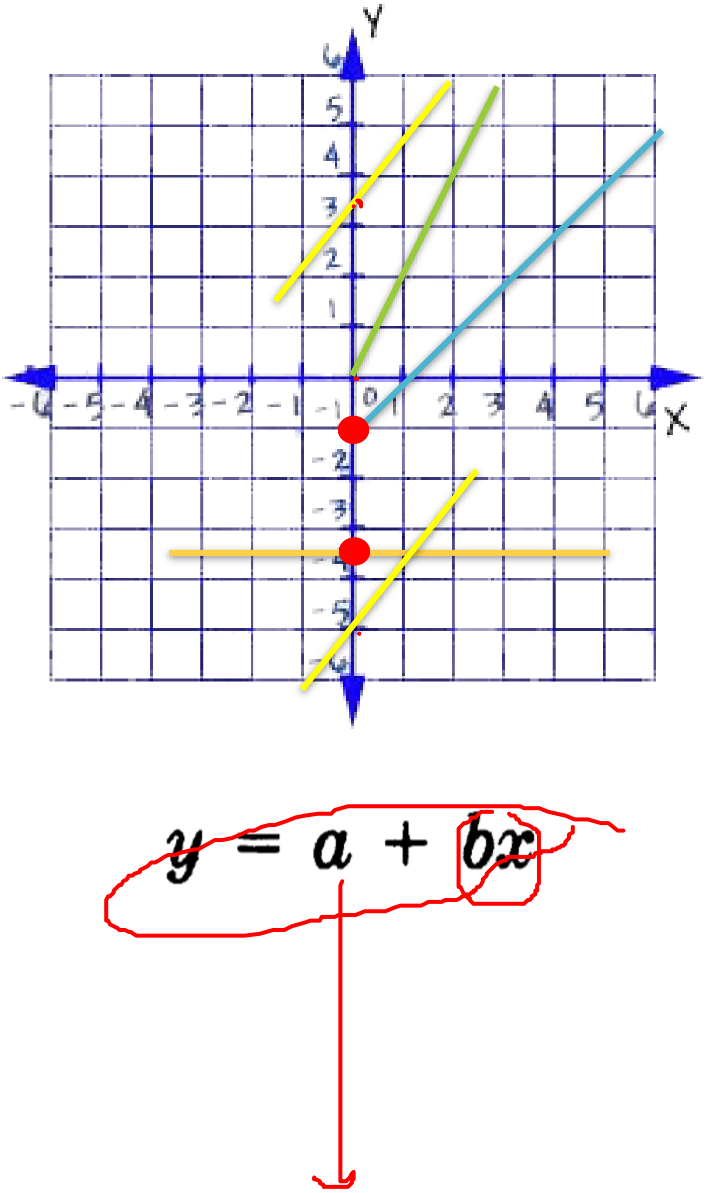
- b constant: is the slope of the line;

$$b = \frac{\Delta y}{\Delta x}$$

- the greater the value of b, the steeper the slope.
- b is also the tangent of the angle that the line makes with the x axis



- **b = 1**, the line makes an angle of 45° with the x axis (tan 45° = 1), and the equation of the line may then be written: **y = a + x**



- When **b = 0**, the line is horizontal (i.e., parallel to the x axis), and the equation reduces to

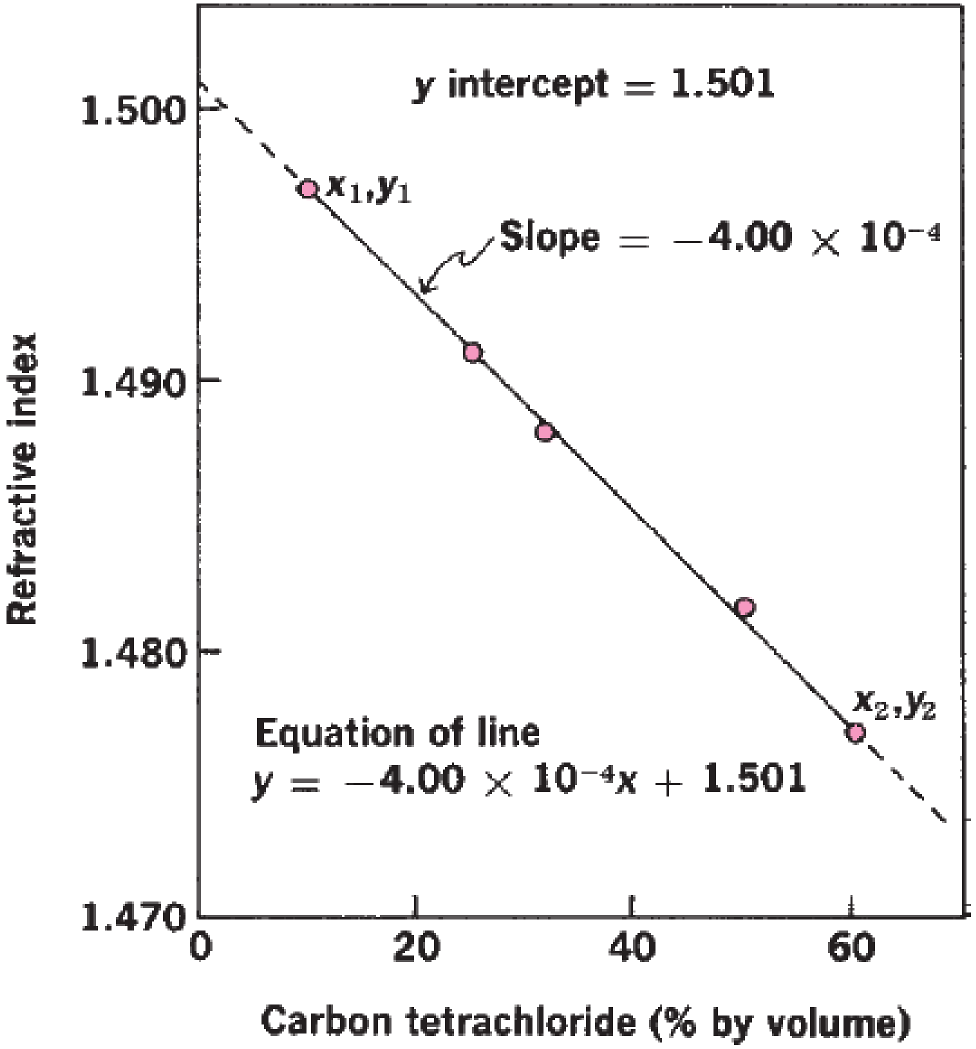
y=a

- The constant **a** is known as the **y intercept** and signifies the point at which the line crosses the y axis.

- When a is **zero,** **y = bx**

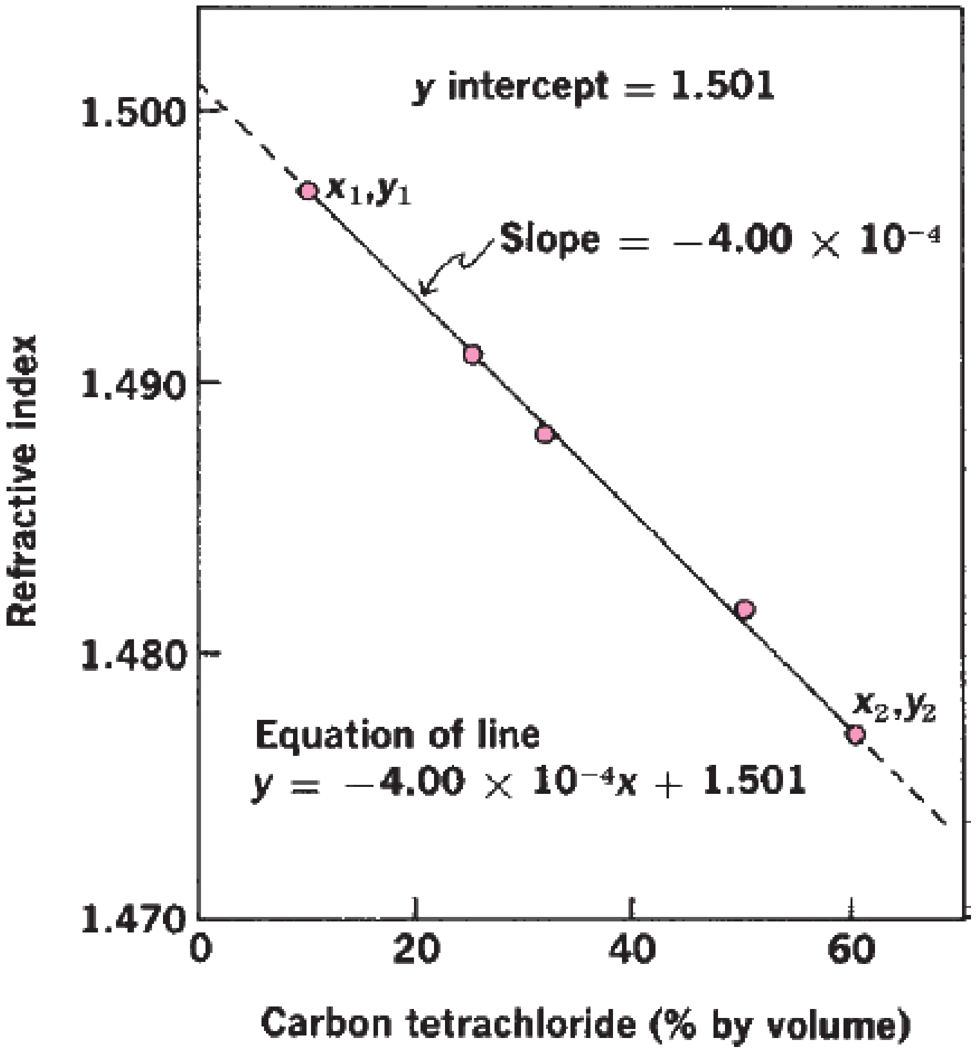
and the line passes through the origin.

Example:



- The results of the determination of the refractive index of a benzene solution containing increasing concentrations of carbon tetrachloride are shown in Table The data are plotted in Figure and are seen to produce a straight line with a negative slope.

Concentration of CCl_4 (x) (Volume %)	Refractive Index (y)
10.0	1.497
25.0	1.491
33.0	1.488
50.0	1.481
60.0	1.477



The equation of the line may be obtained by using the two-point form of the linear equation

$$y - y_1 = \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$$

The method involves selecting two widely separated points

(x1, y1) and (x2, y2) on the line and substituting into the two point

equation.

EXAMPLE 1–9

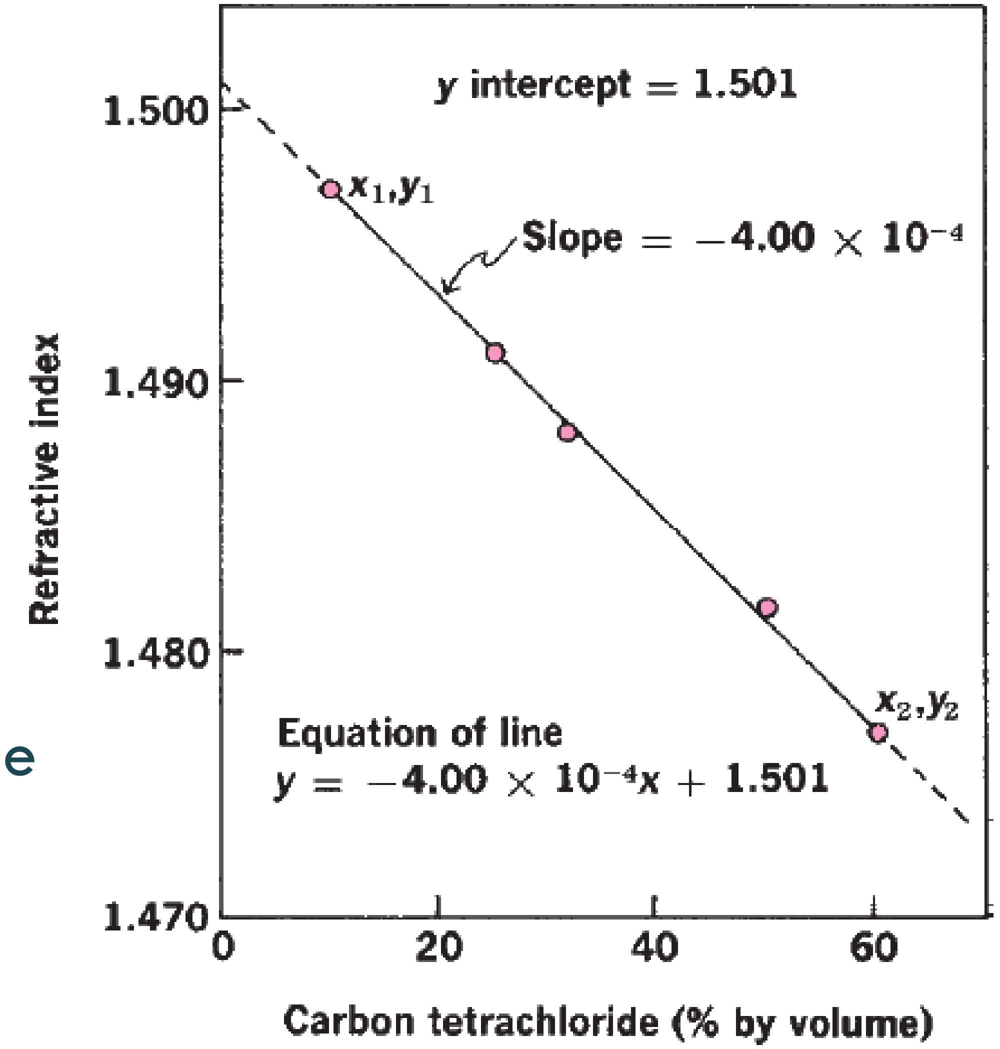
Referring to Figure 1–2, let 10.0% be x_1 and its corresponding y value 1.497 be y_1; let 60.0% be x_2 and let 1.477 be y_2. The equation then becomes

$$y - 1.497 = \frac{1.477 - 1.497}{60.0 - 10.0}(x - 10.0)$$

$$y - 1.497 = -4.00 \times 10^{-4}(x - 10.0)$$

$$y = -4.00 \times 10^{-4}x + 1.501$$

- The value –4.00 × 10–4 is the slope of the straight line and corresponds to b
- A negative value for b indicates that y decreases with increasing values of x,
- The value 1.501 is the y intercept and corresponds to a in equation
- It can be obtained from the plot in Figure 1–2 by extrapolating (extending) the
- line upward to the left until it intersects the y axis

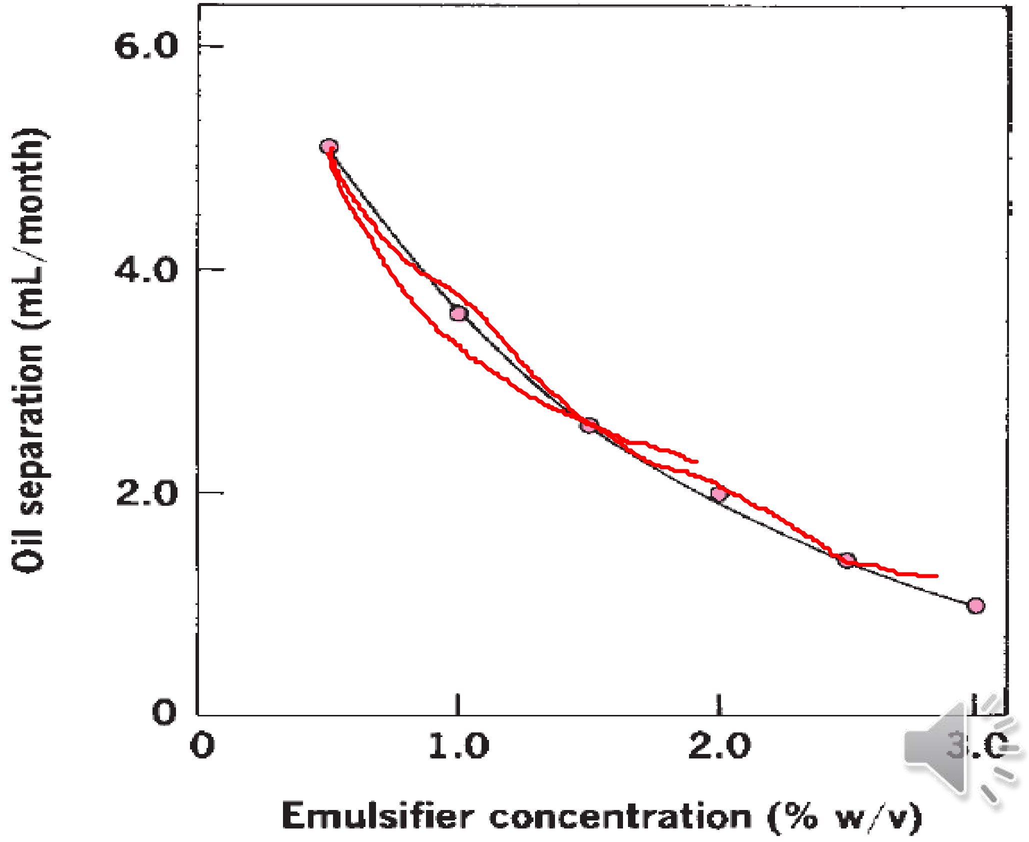


- Not all experimental data form straight lines.
- Equations containing **x2** or **y2** are known as second-degree or quadratic equations, and graphs of these equations yield parabolas, hyperbolas, ellipses, and circles.

- Data relating the amount of oil separating from an emulsion per month (dependent variable, y) as a function of the emulsifier concentration (independent variable, x) are collected in Table 1–4.
- The data from this experiment may be plotted in several ways.
- In Figure 1–3, the oil separation y is plotted as ordinate against the emulsifier concentration x as abscissa on a rectangular coordinate grid.

TABLE 1–4
EMULSION STABILITY AS A FUNCTION OF EMULSIFIER CONCENTRATION

Emulsifier (x) (% Concentration)	Oil Separation (y) (mL/month)	Logarithm of Oil Separation (log y)
0.50	5.10	0.708
1.00	3.60	0.556
1.50	2.60	0.415
2.00	2.00	0.301
2.50	1.40	0.146
3.00	1.00	0.000



In Figure 1–4, the logarithm of the oil separation is plotted against the concentration.

In Figure 1–5, the data are plotted using semilogarithmic scale, consisting of a logarithmic scale on the vertical axis and a linear scale on the horizontal axis.