HANDOUT SET

GENERAL CHEMISTRY I

Periodic Table of the Elements

	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 **H** 1.00794																	2 **He** 4.00262
2	3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.0067	8 **O** 15.9994	9 **F** 18.9984	10 **Ne** 20.179
3	11 **Na** 22.9898	12 **Mg** 24.305											13 **Al** 26.98154	14 **Si** 28.0855	15 **P** 30.97376	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
4	19 **K** 39.0983	20 **Ca** 40.078	21 **Sc** 44.9559	22 **Ti** 47.88	23 **V** 50.9415	24 **Cr** 51.9961	25 **Mn** 54.9380	26 **Fe** 55.847	27 **Co** 58.9332	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.59	33 **As** 74.9216	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
5	37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.9059	40 **Zr** 91.224	41 **Nb** 92.9064	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.9055	46 **Pd** 106.42	47 **Ag** 107.8682	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.710	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.9045	54 **Xe** 131.29
6	55 **Cs** 132.9054	56 **Ba** 137.34	57 **La*** 138.91	72 **Hf** 178.49	73 **Ta** 180.9479	74 **W** 183.85	75 **Re** 186.207	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.9665	80 **Hg** 200.59	81 **Tl** 204.383	82 **Pb** 207.2	83 **Bi** 208.9804	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** 226.0254	89 **Ac**** 227.0278	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (264)	108 **Hs** (265)	109 **Mt** (266)	110 (270)	111 (272)	112 ******* (277)						

*Lanthanides	58 **Ce** 140.12	59 **Pr** 140.9077	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.925	66 **Dy** 162.50	67 **Ho** 164.930	68 **Er** 167.26	69 **Tm** 168.9342	70 **Yb** 173.04	71 **Lu** 174.967
**Actinides	90 **Th** 232.038	91 **Pa** 231.0659	92 **U** 238.0289	93 **Np** 237.0482	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Mass numbers in parenthesis are the mass numbers of the most stable isotopes. As of 1997 elements 110-112 have not been named.

***Peter Armbruster and Sigurd Hofman synthesized a single atom at the Heavy-Ion Research Center in Darmstadt, Germany in 1996. The atom survived for 280 μs after which it decayed to element 110 by loss of an α-particle

Chapter 1

Matter
Its Properties and Measurement

MATTER – ITS PROPERTIES AND MEASUREMENT

CHAPTER 1

INTRODUCTION

Lecture introduced the role of chemistry in the physical sciences and the *Scientific Method*. Further, we discussed a brief historical perspective of the origin of modern chemistry and tried to develop the idea that some of the theoretical principles we use today have evolved over hundreds or thousands of years. This chapter introduces many of the fundamental definitions used by scientists and emphasizes that the vocabulary is rigorously defined in the scientific context. Chapter 1 concludes with an in-depth discussion of the mathematical techniques used in the physical sciences.

GOALS

1. As a total part of your science education, you should understand how chemistry relates to the other physical and life sciences.
2. The historical perspectives of science is important in the total understanding of how and why science and technology is in its current state of development.
3. You must be comfortable with the terms and definitions outlined in lab, lecture, and text.
7. On the other hand, unlike as perhaps defined in earlier science courses, some definitions are not very strict. For example, the difference between a physical and chemical property or a physical and chemical change may not be very precisely defined.
4. You must also be comfortable with measurements, the SI units of measure, and the SI base-units and prefixes.
5. The method of problem-solving known as *Dimensional Analysis*, *Factor-Label*, and *Conversion-Factor* is an extremely powerful technique that you should be familiar with. It is not absolutely essential that you master or even use the technique, but its superior strategies to working quantitative problems generally far outweigh all other techniques. Whenever possible you should avoid the *Ratio* method. On occasion, it is necessary to memorize an equation (*e.g.* temperature conversions) but this situation is rare if dimensional analysis is used.
6. While discussed mostly in the laboratory, knowledge of significant figures and how they are handled in calculations is important and will be graded somewhat strictly.

DEFINITIONS

You should have a working knowledge of at least these terms and any others used in lecture.

Scientific Method
Experiment
Hypothesis
Law
Theory
Property
Intensive
Extensive
Chemical property
Physical property
Chemical change
Physical change
Chemical reaction

Matter
Mass
Weight
Substance
Mixture
Homogeneous
Heterogeneous
Element
Atom
Compound
Molecule
Solid, liquid, gas
SI units

SI prefixes
Derived units
Dimensional Analysis
Conversion factor
Density
Percent
Significant figure
Most significant digit
Least significant digit
Precision
Accuracy
Systematic error
Random error

Some Definitions

Matter	Anything that occupies space
Mass	Quantity of matter
Weight	Effect of gravity on mass (not technically interchangeable with mass)
Substance	Matter with definite composition and distinct properties
Mixture	Combination of two or more substances in which each substance retains its chemical identity.
Heterogeneous	Individual substances retain their discreet boundaries
Homogeneous	Individual substances lose their discreet boundaries and are indistinguishable from the whole

The composition of a mixture is variable and the components can be separated by purely physical means.

Element	Pure substance that cannot be broken down into simpler substances by chemical means
Compound	Pure substance composed of 2 or more elements chemically united in fixed proportions by mass
Molecule	Single unit of a compound that retains the identity and properties of the compound
Atom	Single unit of an element that retains the identity and properties of the element

SI Base Units

Base Quantity	Unit	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Temperature	Kelvin	K
Quantity of Substance	Mole	mol
Electrical Charge	Coulomb	C
Electrical Current	Ampere	A
Luminous intensity	Candela	cd

SI Prefixes

Prefix	Symbol	Value	Example
Tera-	T	10^{12} (1,000,000,000,000)	1 terameter = 1 x 10^{12} m
Giga-	G	10^{9} (1,000,000,000)	1.21 gigawatts = 1.21 x 10^{9} Watts
Mega-	M	10^{6} (1,000,000)	1 megajoule = 1 x 10^{6} J
Kilo-	k	10^{3} (1,000)	1 kilometer = 1 x 10^{3} m
Deca-	D (not SI)	10	1 decagram = 10 g
Deci-	d (not SI)	10^{-1} (0.1)	1 decimeter = 0.1 m
Centi-	c (not SI)	10^{-2} (0.01)	1 centimeter = 0.01 m
Milli-	m	10^{-3} (0.001)	1 milligram = 10^{-3} g
Micro-	µ	10^{-6} (0.000001)	1 microliter = 10^{-6} L
Nano-	n	10^{-9} (0.000000001)	1 nanometer = 10^{-9} m
Pico-	p	10^{-12} (0.000000000001)	1 picomole = 10^{-12} mol
Femto-	f	10^{-15} (0.000000000000001)	1 femtogram = 10^{-15} g

Magnitude and Scientific (Exponential) Notation

1. Convert to scientific notation:

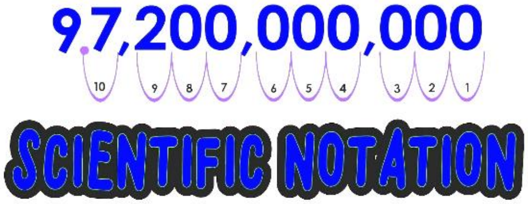
   100,000, precise to ±1

   ten thousand, precise to ± 1000

   0.000400

   0.0003

   275.3



2. Convert to exponential notation:

   175,906

   0.0000605

   two and a half million, precise to ±100

   two and a half billion, precise to ± one million.

3. Express each of the following in SI base units using scientific notation:

   432 kg

   624 ps

   1024 ng

   93,000 km, precise to ±10

   1 day

   0.0426 in.

Do this...

$$m = 2.5\,\text{mL} \times 1.00\,\tfrac{\text{g}}{\text{mL}} = 2.5\,\text{g H}_2\text{O}$$

$$m = 2.5\,\text{g H}_2\text{O} \times \frac{1000\,\text{mg}}{\text{g}} = 2{,}500\,\text{mg H}_2\text{O}$$

or...

$$m = 2.5\,\text{mL} \times 1.00\,\tfrac{\text{g}}{\text{mL}} \times \frac{1000\,\text{mg}}{\text{g}} = 2{,}500\,\text{mg H}_2\text{O}$$

but not...

$$m = 2.5\,\text{mL} \times 1.00\,\tfrac{\text{g}}{\text{mL}} = 2.5\,\text{g H}_2\text{O} \times \frac{1000\,\text{mg}}{\text{g}} = 2{,}500\,\text{mg H}_2\text{O}$$

SI Unit Conversions

1. Express each of the following in SI base units using scientific notation:

   a. 1 week

   b. 1.35 mm

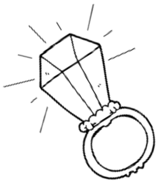
   c. 15 miles

   d. 4.567 μs

   e. 6.45 mL

   f. 47 kg

2. The mass unit most commonly used for precious stones is the carat: 1 carat = 3.0865 grains (not exact), and 1 gram = 15.4 grains (not exact). Find the total mass in kilograms (kg) of a ring that contains a 0.50 carat diamond and 7.00 grams of gold.



3. What is the total mass in grams, expressed in scientific notation with the correct number of significant figures, of a solution containing 2.000 kg of water, 6.5 g of sodium chloride, and 47.546 g of sugar?

Dimensional Analysis
A Chemical Problem

Carbon atoms weigh 12.01 g/mol. A mol is 6.022×10^{23} atoms. How many atoms of carbon are present in a 0.5 carat diamond? (A carat is 200 mg exactly.)

Dimensional Analysis
Example Density Problem

The density of lead is 11.34 g/mL. What Is the density of lead in pounds per cubic foot? Could you easily lift a 1.25 cubic foot block of lead? (Hint: calculate the weight of 1.25 cubic feet of Pb.)

Dimensional Analysis
A More Complex Problem

For a touch of reality (or absurdity) with particular appeal for the "trivia buff', try your hand at the following problem involving *dimensional analysis.* The problem is based on data given in the *Guinness Book of World Records.*

Problem:

The Amazon River has the greatest flow of any river in the world, discharging an average of 4,200,000 (2 significant figures) cubic feet of water per second into the Atlantic Ocean. If there are 1.48×10^{18} tons of water on Earth, how many years are required for the Amazon's flow to equal the Earth's water supply? (Assume a density of 1.0 g/cm^3 for all water.)

Fictional 19th century explorer, Hercules Peabody, charting the darkest and most forbidding parts of the Amazon and fighting off a live plesiosaur that had somehow survived in the murky waters of the great river.

Mass-Mass Relationships in Calculations: Percentage and ppm

1. An aqueous solution of acetic acid ($HC_2H_3O_2$) is reported as 4.70% by mass (4.70% $^{w}/_{w}$). The density of the solution was determined to be 1.006 g/mL.

    a. What mass of the solution will contain 10.0 g of acetic acid?

    b. What volume (in microliters) of the acetic acid solution will contain 5.0 mg of acetic acid?

2. Many municipalities fluoridate their domestic drinking water prior to delivering the water to the customer. The fluoride helps to prevent dental caries (cavities) for people who live in areas where fluoride levels are naturally low. A typical concentration of fluoride is 0.70 ppm in the drinking water.

    At the typical concentration, what mass of fluorine will be found in a 12 oz (355 mL) glass of water. Assume the density of tap water is the same as pure water.

More Unit Conversions

1. What is the mass of 1 quart of water (1 L = 1.057 quarts)?

2. What is the mass of 1 quart of mercury (1 L = 1.057 quarts)?

3. Convert each of the following into SI units:

   a. engine displacement of 454 cubic inches

   b. car speed of 35 mph

   c. height of 6 feet 9 inches

   d. boulder mass of 227 pounds.

   e. gold nugget mass of 1.5 ounces

   f. light speed of 6.71×10^8 mph

   g. hike length of 11 miles

   h. car mileage of 32 miles/gallon.

Complex Units

1. A plastic block measures 15.5 cm by 4.6 cm by 1.75 cm, and its mass is 98.456 g. Compute the density of the plastic.

2. A penny has a diameter of 1.8 cm and a thickness of 0.15 cm, and its mass is 2.50 g. Compute the density of the penny (cylinder volume, $V = \pi r^2 h$).

3. Calculate the volume of an aluminum spoon whose mass is 15.4 g.

4. Calculate the volume of a quartz crystal of mass 0.246 g. (You may need to look up the density of quartz.)

Important Periodic Table Terms and Features

Regions
- Representative elements
- Transition elements
- Lanthanides
- Actinides

Metals
- Location on Table
- Properties

Nonmetals
- Location on Table
- Properties

Metalloids (semimetals)
- Location on Table
- Properties

Families (groups)
- Alkali metals
- Alkaline earth metals
- Chalcogens
- Halogens
- Noble gases
- Coinage Metals

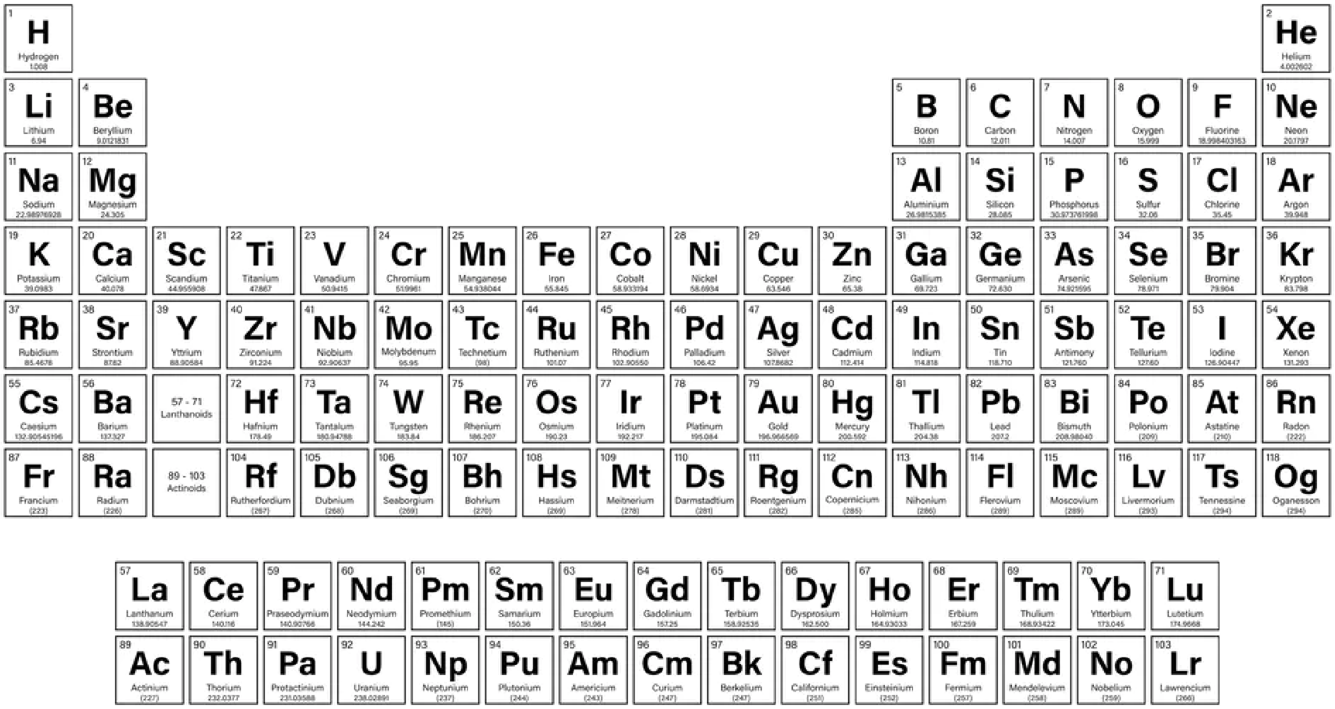
Periods
- Short periods
- Long periods

Blocks
- *s*-block
- *p*-block
- *d*-block
- *f*-block

Elements which naturally occur as homonuclear diatomic or polyatomic molecules

H_2 N_2 O_2 X_2 (X is all halogens) P_4 (one of several forms) S_8 (one of several forms)

C has several allotropes: graphite, diamond, fullerenes (e.g. C_{60} buckminsterfullerene or ‘bucky-ball”)



ORIGINS OF THE ELEMENT'S NAMES

Element	Symbol	Atomic Number	Origin of Name	Some Important Uses
Actinium	Ac	89	Greek, *Aktinos* (ray) for its radioactivity	Neutron source in nuclear energy applications
Aluminum	Al	13	Latin, *Alumen* (alum)	Lightweight alloys, wire, cans and foils, rugged reflective coatings on mirrors, abrasives, lasers (in the form of ruby and sapphire)
Americium	Am	95	Named after the American continent	Smoke detectors
Antimony	Sb	51	Latin, *stibium* = mark; Greek, *anthemonium*	Originally used as the sulfide by Asian women to darken their eyebrows. Name is possibly derived from the Arabic *al ithmid*, the name of Sb_2S_3 used for mascara. Used in semiconductor technology, metal alloys to increase hardness and strength, batteries, ordinance, flame retardants, paints, pharmaceuticals
Argon	Ar	18	Greek, *Aergon* (lazy one, no work, no action)	Used in incorrectly-named "neon" lights to produce red emission, electric light bulbs as an inert gas filler, fluorescent light bulbs, inert gas in inert-gas welding, semiconductor technology, inert gas atmosphere in chemical synthesis
Arsenic	As	33	Greek, *Arsenikos* (brave, male)	Semiconductors, bronzing, pyrotechnics, lasers
Astatine	At	85	Greek, *A-statos* (not lasting or not stable)	Radioactive element with 7.5 h half-life. There is probably less than 1 mg of the isolated element on Earth. There is no industrial use for astatine.
Barium	Ba	56	Greek, *Baryos* (heavy)	As the sulfate in x-ray analysis of the intestines, pyrotechnics, paint pigments
Berkelium	Bk	97	Named for Berkeley, the city of discovery	Currently, there are no industrial uses
Beryllium	Be	4	Greek, *Beryllos* for the mineral beryl	Hardener in metal alloys, ceramics, windows for x-ray sources
Bismuth	Bi	83	German, *Wiese* and *Muten* or more commonly accepted *Weisse Masse* meaning white mass	OTC medications such as PeptoBismol®, iron alloys, catalysts, thermocouples, fire extinguishers
Bohrium	Bh	107	Named in honor of Niels Bohr	No industrial use
Boron	B	5	Arabic, *Bauraq*; Persian, *Burah* for borax, $Na_2B_4O_7 \bullet 10H_2O$ where boron is found	Insecticides (as boric acid), pyrotechnics, borax, paint, ceramics, borosilicate glass (*e.g.*, Pyrex and Kimax), nuclear reactors,
Bromine	Br	35	Greek, *Bromos* (bad odor or stink)	Flame retardants, dyes, pharmaceuticals, photography (as AgBr), fumigants, pesticides, pool water disinfection
Cadmium	Cd	48	From *cadmium fornacum* (furnace calamine). Calamine ($ZnCO_3$) was a mineral found in *Kadmeia* in Ancient Greece.	Specialty solders and other alloys, iron coating to prevent rust, batteries, nuclear control rods, television CRT phosphors, paint pigment
Calcium	Ca	20	Greek, *kylix*; Latin, *calx* (chalk)	Cement, reducing agent, used in the preparation of various alloys, formerly used in vacuum tubes
Californium	Cf	98	Named for California, the state of discovery	^{252}Cf foils are used as a source of fission fragments for research purposes, neutron source for detectors and scintillation counters, moisture gauges for the determination of water and oil-bearing layers in oil wells

Element	Symbol	Atomic Number	Origin of Name	Some Important Uses
Carbon	C	6	From Latin, *carbo* (charcoal)	As graphite for lubrication, as a fossil fuel (coal), for hardening steel, radiological dating, basic “building block” element of millions of organic compounds
Cerium	Ce	58	Latin, *Ceres* the Roman goddess of harvest and the name of the first asteroid discovered	Oxide is one component of incandescent gas mantles (Coleman lanterns), catalyst in "self-cleaning" ovens, oxide used as a polishing compound, nuclear applications
Cesium	Cs	55	Latin, *Caesius* (blue of the upper part of the firmament) from the blue color of the vapor excited to incandescence	Catalyst, photoelectric effect detectors, atomic clocks, IR emitters, IR optics
Chlorine	Cl	17	Greek, *khloros* (yellow-green) for the color of the gas	Disinfection of water, textiles, pharmaceuticals, insecticides, herbicides, paints, plastics, solvents, bleach
Chromium	Cr	24	Greek, *khroma* (color) for the many colored compounds it produces	Metal alloys, hardening steel, corrosion resistant surfaces, gives glass a green color and rubies their red color, paint pigments, leather tanning
Cobalt	Co	27	German, *kobold* (evil sprite)	Paint pigments, strong Alnico magnets, high strength alloys for turbine engines, stainless steel, ^{60}Co is used for radiotherapy in cancer treatment
Copper	Cu	29	Greek, *Kyprion*; Latin, *Cuprum*	Wire, coins, the electrical industry, copper sulfate is used to kill water-borne fungus and algae
Curium	Cm	96	In honor of Marie and Pierre Curie	Alpha particle source, used aboard Mars landers in the Alpha Proton X-Ray Spectrometer
Darmstadtium	Ds	110	Named for Darmstadt, Germany, city of first synthesis	Since only a few atoms have ever been made, this element has no uses
Dubnium	Db	105	Named for Dubnia, the location of its first production	No known use
Dysprosium	Dy	66	Greek "*dysprositos*" (hard to obtain) since it was difficult to separate it from a holmium mineral	Possible use in nuclear reactor control, solid-state lasers
Einsteinium	Es	99	Named in honor of Albert Einstein	So little has been made that there are no uses
Erbium	Er	68	Named after the town Ytterby, Sweden since it was found in the mineral *ytterite*	Glass and ceramics, nuclear industry, reduces brittleness of hard metals
Europium	Eu	63	Named for the continent	Alloys, nuclear reactor control, with yttrium makes the phosphor that produces the red color in television CRTs, lasers
Fermium	Fm	100	Named in honor of Enrico Fermi	So little has been made that there are no uses
Fluorine	F	9	Latin, *Fluere* (flow) for the ease of melting fluorspar	In domestic drinking water to prevent tooth decay, plastics, Teflon, as hydrofluoric acid for decorative glass etching, refrigerants
Francium	Fr	87	Named for France, homeland of its discoverer	So little of the element exists that no uses are possible
Gadolinium	Gd	64	After Sir Johan Gadolin of Turku, the first to study the mineral gadolinite	Contrast dyes in MRI analysis, television cathode ray tubes, alloys, compact disks, superconductors

Element	Symbol	Atomic Number	Origin of Name	Some Important Uses
Gallium	Ga	31	Latin, *France* for its country of discovery	Semiconductors, solid-state lasers, alloys, neutrino detectors
Germanium	Ge	32	After Germany, its country of discovery	Transistors and other semiconductors, alloys, phosphor in some fluorescent lamps, catalysis, optics – especially far-IR, radiation detectors
Gold	Au	79	Latin, *Aurum* (yellow) and from Aurora, goddess of dawn	coinage and currency, jewelry, decoration, dentistry, IR mirrors, electroplating, photography, anti-arthritis drugs, electrical connectors
Hafnium	Hf	72	Latin for Copenhagen, the city of discovery	Nuclear control rods, gas filled and incandescent lamps
Hassium	Hs	108	Latin, *Hassias* (Germany). Named for the German State of Hesse	Since only a few atoms have ever been synthesized, there is no use for the element.
Helium	He	2	Greek, *Helios* (Sun) for where helium was discovered (N. Lockyer)	Balloons, lighter-than-air aircraft, inert gas shield for arc welding (especially Al), coolant gas for nuclear reactors, in liquefied form a cryogenic gas, mixed-air breathing gas modifier for ultra-deep divers, carrier gas in gas chromatography
Holmium	Ho	67	Named for *Holmium*, the ancient name of Stockholm, Sweden	Alloys, optics
Hydrogen	H	1	Greek, *Hydros* (water) and *Gen* (producing)	Hydrogenation of fats and oils, production of ammonia, rocket fuel for the space shuttle, reduction of metallic ores, formerly used in lighter-than-air craft, cryogenics, tritium (^3H) is used medicinally (*e.g.*, in PET scan technology) and in thermonuclear weapons.
Indium	In	49	Latin, *indicum*; Greek, *indicon* for the indigo line emission from the excited state atom.	Metal alloys, semiconductors, corrosion resistant mirrors
Iodine	I	53	Greek, *Ioeides* (violet) for the color of its vapor	Medicinal disinfectant, pharmaceuticals, photography (as AgI), nutritional supplement (as KI in table salt)
Iridium	Ir	77	Greek, *Iris* (rainbow) because its salts show a variety of colors	High temperature crucibles and apparatus, electrical and electronics applications, hardening agent for platinum, alloys with osmium for pen tips and compass bearings
Iron	Fe	26	Arabic(?), *Ferrum*; Anglo-Saxon, *Iren*	Probably smelted first, in extreme secret, by the Egyptians and/or Hittites in 3000 B.C. By 1200 B.C., the start of the Iron Age, smelting and use of iron extensively spread. Used in steel and thousands of other uses
Krypton	Kr	36	Greek, *Kryptos* (hidden) for the gas “hiding” in distilled liquefied air	Used in place of xenon in some photographic flash units, lasers, fill-gas in some fluorescent light bulbs
Lanthanum	La	57	Greek, *Lanthanos* (escapes notice) since it was hidden in the mineral cerite for nearly 40 years after a compound of cerium was discovered	Metal alloys, lighter flints
Lawrencium	Lr	103	Named in honor of Ernest Lawrence	So little has been made that there are no uses

Element	Symbol	Atomic Number	Origin of Name	Some Important Uses
Lead	Pb	82	Latin, *Plumbum*	Ancient uses include water-pipes, writing tablets, coins, and cooking utensils. Modern uses include: metal and the oxide in lead-acid (automobile) batteries, ammunition, radiation shielding around x-ray equipment and nuclear reactors, paints, the oxide is used in producing fine “leaded-crystal” glass, solder
Lithium	Li	3	Greek, *Lithos* (stone)	Some salts are used to treat manic-depressive disorders, lubricants, CO2 scrubber in manned space craft, aircraft alloys, organic chemistry synthesis, batteries
Lutetium	Lu	71	Latin, ancient name of Paris	Catalysts, alloys
Magnesium	Mg	12	From *magnesia*	Used in flares, pyrotechnics, military ordnance, alloys for use in aircraft, automobile engines, and wheels, OTC pharmaceuticals such as the hydroxide (milk of magnesia) and sulfate (Epsom salts)
Manganese	Mn	25	From *magnesia nigri* (black magnesia), which distinguishes it from *magnesia alba* (white magnesia), a source of magnesium	As the permanganate a strong oxidizing agent, in steel alloys to improve strength, wear resistance, and hardness, magnets, batteries, glasses and ceramics, responsible for the color of amethyst, required for biological utilization of vitamin B_1
Meitnerium	Mt	109	Named for early 20th century physicist Lise Meitner	No industrial use
Mendelevium	Md	101	Named for Dmitri Mendeleev	No industrial use
Mercury	Hg	80	Latin, *Hydrargyrum* from Greek, *Hydro-argyros* (water-silver)	Thermometers, barometers, diffusion pumps, and many other instruments, mercury switches and other electrical apparatus, batteries, mercury-vapor lamps and advertising signs, dental amalgams
Molybdenum	Mo	42	Greek, *Molybdos* (lead)	Hardens steel alloys, aircraft industry, essential for nutrition, lubricants
Neodymium	Nd	60	From the Greek *neos didymos* (new twin)	Discovered in 1885 by Austrian chemist Carl Auer von Welsbach who separated didymium into two elements, one of which he called neodymium (new twin). Used in powerful permanent magnets, colorant for glasses and glazes, metal alloys, welding goggles, solid-state lasers, calibration glasses in spectroscopy.
Neon	Ne	10	Greek, *Neos* (new)	Largest use in making neon emission tubes for signs, lasers, cryogenic refrigerant when liquefied
Neptunium	Np	93	From the planet Neptune – next element after Uranium and next planet after Uranus.	By product of nuclear fission, ^{237}Np is a component in neutron detection instruments
Nickel	Ni	28	From German *Kupfer-nickel* (devil copper) since the ore resembles copper ore.	stainless steel and other corrosion-resistant alloys, coinage, electroplating, hydrogenation catalysts, batteries (*e.g.*, Ni-Cd and nickel metal-hydride batteries)
Niobium	Nb	41	From Niobe, the daughter of Tantalus in Greek mythology	A component of some stainless steels, other alloys, welding rods, nuclear reactors, wire for superconducting magnets, tongue and navel studs
Nitrogen	N	7	Greek, *niter* = saltpeter	millions of chemical compounds, all plant and animal cells, fertilizers, ammonia

Element	Symbol	Atomic Number	Origin of Name	Some Important Uses
Nobelium	No	102	Named in honor of Alfred Nobel	So little has been made that there are no uses
Osmium	Os	76	Greek, *Osme* (odor) for the disagreeable odor of OsO_4	Almost entirely used to produce very hard alloys with other metals of the platinum group, for fountain pen tips, instrument pivots and bearings, and electrical contacts
Oxygen	O	8	Greek, *oxys* (acid) and *genes* (forming)	Respiration, combustion, millions of chemical compounds
Palladium	Pd	46	Greek, *Pallas* goddess of wisdom and name of second asteroid discovered	Jewelry (e.g., production of "white" gold), catalyst, dentistry, electrochemical electrode applications
Phosphorus	P	15	Greek for light producing	All plant and animal cells, fertilizers, detergents. Discovery of phosphorus is the earliest for which its discoverer is known.
Platinum	Pt	78	Spanish, *platina* (silver)	Jewelry, jet engines and missiles, corrosion resistance, catalysts
Plutonium	Pu	94	From the planet Pluto – next element after Neptunium and next planet after Neptune.	Nuclear power plants, nuclear weapons
Polonium	Po	84	Named after Poland, homeland of its discoverer (Marie Curie)	Neutron source in nuclear energy, "static-free" brushes, nuclear reactor fuel in some spacecraft
Potassium	K	19	English, *potash* German, *kalium*	Fertilizers, present in thousands of compounds, essential for proper neural activity
Praseodymium	Pr	59	Greek, *Praseios* (green color of a leek) for the color of most of its salts	Alloys, Misch metal in cigarette lighters, glasses and ceramics, carbon arc-lights
Promethium	Pm	61	From mythology, Prometheus, the god who stole fire from heaven and gave it to humans	Currently little industrial use. All promethium on Earth is synthetic.
Protactinium	Pa	91	Greek, *Protos* (prior) for being the parent element that produces the daughter element, actinium.	No known industrial use
Radium	Ra	88	Latin, *Radius* (ray) for the sulfate salt which glows in the dark (disc. by M. and P. Curie)	Formerly used for self-luminescent watch and clock faces, formerly used in cancer radio-therapy
Radon	Rn	86	Latin, *Radius* (ray) for being produced in air exposed to radium	Little industrial use, gas with highest known density
Rhenium	Re	75	Latin for the Rhenany-Reinland, birthplace of Ida Tacke, one of the discoverers	90% of rhenium is used for catalysts, tungsten and molybdenum-based alloys, filaments for mass spectrographs and ion gauges, superconductors, thermocouples
Rhodium	Rh	45	Greek, *Rhodon* (rose) for its rose-colored salts	Automobile catalytic converters, high temperature thermocouple elements, high temperature crucibles, electrical contact material, catalysts, jewelry
Rubidium	Rb	37	Latin, *Rubidus* (deepest red) from the strong red emission of excited gas-phase rubidium atoms	possible use in "ion engines" for space vehicles, photocells, specialty glasses

Element	Symbol	Atomic Number	Origin of Name	Some Important Uses
Ruthenium	Ru	44	Latin, *Russia*	Alloyed into platinum and palladium to harden the metal, added to titanium for improved corrosion resistance of titanium, catalyst
Rutherfordium	Rf	104	In honor of New Zealand physicist, Ernest Rutherford	No industrial use
Samarium	Sm	62	From Samarskite, the mineral source of samarium	High-field magnets, carbon-arc lighting, lasers, infrared detectors, catalysts
Scandium	Sc	21	For Scandinavia, homeland of Lars Fredrik Nilson (1840-1899), discoverer of the element	No significant industrial use
Seaborgium	Sg	106	After the American chemist, Glenn Seaborg	No industrial use
Selenium	Se	34	Greek, *Selene* (Moon)	Semiconductor technology, photocells, photography, stainless steel alloys
Silicon	Si	14	Latin, *silex* (flint)	Semiconductors, computer chips, abrasives, tools, water repellents
Silver	Ag	47	Latin, *argentum*	Coinage, photographic chemicals, jewelry silverware, electrical contacts, batteries
Sodium	Na	11	Hebrew, *Neter*; Latin, *Nitrium*; German, *natrium*	Ubiquitous, many compounds such as salt (NaCl), lye (NaOH), essential for proper neuronal activity
Strontium	Sr	38	From the mineral *strontianite* found in the town of Strontian, Argyleshire, Scotland	Specialty optical glasses, pyrotechnics to produce red fireworks, road and signal flares, nuclear reactors, television CRTs
Sulfur	S	16	Sanskrit, *sulvere*	Gunpowder, automobile tires, sulfuric acid, paper, fumigants, fertilizers
Tantalum	Ta	73	From mythology, *Tantalus*, son of Jupiter, was condemned to hell, standing to his neck in water. But the water sank when he stooped to drink. Ta_2O_5 does not take in water, nor dissolve in acids.	Optical glass with high refractive index, ductile steel alloys with high melting point and high strength, military ordnance, nuclear reactors, high biological tolerance makes it suitable for surgical use, electronic components
Technecium	Tc	43	Greek, *technitos* (artificial). Formerly masurium, Ma	^{95}Tc radioactive tracer, corrosion inhibition in steel, superconductive below 11 K, medical imaging agents
Tellurium	Te	52	Latin, *Tellus* (Earth)	Semiconductors, metal alloys, ceramic and glass colorants
Terbium	Tb	65	Named after the town Ytterby, Sweden since it was found in the mineral *ytterite*	Alloys, lasers, semiconductor technology
Thallium	Tl	81	Latin, *Thallus* (sprouting green twig) for the brilliant green emission from the excited thallium vapor	Extremely toxic metal. Used in IR detectors and visible light photocells, formerly used in rodenticides and pesticides, specialty glasses

Element	Symbol	Atomic Number	Origin of Name	Some Important Uses
Thorium	Th	90	After *Thor*, Norse god of war	Preparation of the "Welsbach mantle", used for portable gas lights (*e.g.*, Coleman lanterns), alloys, laboratory crucibles, high refractive index glasses, catalysts.
Thulium	Tm	69	Named after Thule, the ancient name of Scandinavia	Alloys, little industrial use
Tin	Sn	50	Latin, *stannum*	Alloys (pewter, bronze, solder), coating of steel for tin cans
Titanium	Ti	22	From the *Titans* (giants) of Greek mythology	Aerospace alloys, medicinal alloys (e.g., artificial hip joints), paint pigments (the largest use of TiO2), artificial gemstones, ship hardware continually exposed to sea water
Tungsten	W	74	Swedish *tung sten* (heavy) German, *wolfram*	Highest melting point element, light bulbs, dental drills, steel alloys
Uranium	U	92	Greek, *Uranos* god of heaven. Named after the planet Uranus	Fuel in nuclear fired power plants, nuclear weapons, starting material for production of Pu
Vanadium	V	23	Named for *Vanadis* (or Freya), the Norse goddess of beauty because of the many colored compounds vanadium forms.	Spring and stainless steels, nuclear industry, ceramics, catalysts, superconductive wires
Xenon	Xe	54	Greek, *Xenos* (stranger)	Photographic flashes and strobes, lasers, UV sterilizing lamps, ion-engines for spacecraft
Ytterbium	Yb	70	Named after the town Ytterby, Sweden since it was found in the mineral *ytterite*	Lasers, steel alloys
Yttrium	Y	39	From the mineral *ytterite*, discovered by Johan Gadolin (also gadolinium)	Phosphors containing yttrium produce the red color in television CRTs, high temperature superconductors, simulated diamonds, lasers, catalyst, alloy to strengthen some soft metals
Zinc	Zn	30	German, *zinke* (spike); Persian, *seng* (stone)	Galvanized nails (zinc-coated), die castings, pigments, cosmetics, some proteins
Zirconium	Zr	40	Arabic, *Zerk* (precious stone)	Used in crucibles for corrosive chemicals, cladding for nuclear reactor fuel rods, steel alloys, superconducting wire (with niobium), gems (as the oxide)

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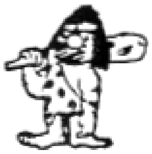
A Brief History of Chemistry

The Prehistoric Period to A.D. 500

Since one of the objectives of chemistry is to acquire knowledge of the properties of matter, every bit of information that prehistoric man found out about the materials around him was, in a sense, a contribution to chemical knowledge. When man first learned, for example, that wood burns and stone does not, and then passed this information along to his fellows, he took the first step along the road toward chemical knowledge.



During these early centuries of man's life on earth., he acquired a great deal. of useful information about the properties of matter. We find direct and indirect evidence in early Biblical writings and other records that, as the years passed, man continued to extend his knowledge of matter and to put it to more and more uses. He learned to dig metals out of the earth, particularly gold, silver, and copper, and to fashion them into useful articles. He discovered how to make glass long before he fully understood its chemical make-up and behavior. Many other substances, such as medicines, oils, and dyes from plants, came into widespread use during this period. Apparently, however, there was no successful attempt to classify or correlate this new-found knowledge, and little progress was made toward a science of chemistry.

The Period of Alchemy, A.D. 500-1600

During these years, many capable and inquiring men turned their attention to the direct observation of matter. The nonsystematized studies by these medieval investigators is called *alchemy*.

Some alchemists made an effort to discover a method of changing base metals, such as lead, into noble metals, such as gold. They engaged in a great deal of experimentation, but they destroyed much of the potential value of their findings by keeping them secret or by misrepresenting the results they actually obtained. The alchemists succeeded, however, in preparing many new substances and in developing scores of useful pieces of apparatus and experimental skills.

The Medical-Chemical Period, 1100-1750

In some ways this period was similar to the period of alchemy. Men experimented widely and began to do some theorizing. In their search for effective medicines, they prepared and purified many new chemical substances, and therefore made valuable contributions to the future. It was during these years that the experimental and the theoretical approaches were successfully wedded for the first time. Francis Bacon first urged that the experimental study of nature be combined with theoretical interpretation. Then, as other scholars adopted Bacon's approach, scientific progress began its swift acceleration toward the spectacular growth rate it has achieved in this century.

Period of Phlogiston Theory, 1700-1777

The scientists of the eighteenth century made an intensive study of the process of burning and developed several theories to explain it. In *1702* Georg Ernst Stahl, a German chemist, proposed that some substance actually was released during the burning of combustible matter. This substance was called 'phlogiston," from the Greek word *phlogistos*, which translates as *flammable*. Stahl's theory was strongly defended for 75 years. One reason for its wide acceptance was the failure of chemists to use weighing devices to determine the exact weights of materials before and after they were burned. This is an interesting example of a theory that seems correct and consistent with a large body of observed facts, but is proved incorrect by more careful quantitative experimental work.

The Modern Period, l777-Present

The modern period of chemistry dates from the work of the French chemist Antoine Lavoisier (1743-1794). We shall be hearing a great deal more of Lavoisier in this book, so let us pause here a moment to give a brief account of this life. He was born in Paris, and at the age of 23 was awarded a gold medal by the Academy of Sciences (of Paris) in recognition of a report he compiled on the problem of city lighting. Most of his life was spent in Paris, and most of his research was done at the Sorbonne. His work on combustion we shall discuss later. In addition, he developed a theory of acids which, though erroneous, was a significant advance over earlier ideas. He also drew up a nomenclature of the elements. Apart from his scientific researches, he served as advisor on many public committees both national and municipal, activities, however, which during the French Revolution led to his death by the guillotine in 1794.

Lavoisier made the first extensive use of weighing devices (balances) in chemical studies, which led to the discovery of the fundamental importance of the conservation of the mass of matter in chemical reactions. Now chemists could measure accurately the amount of matter used and produced in chemical reactions. And on the basis of these exact experimental data, they could proceed to develop acceptable theories and precise chemical laws. This great step forward raised chemistry to the status of an exact science. During the succeeding years, development sped along at an ever-increasing rate, providing the impetus for the discoveries that mark our own highly advanced technical age.