CHEMISTRY

Laws of Matter Up-to-Date

1. A single ATOM is the tiniest particle of any chemical element that can exist by itself and retain the qualities that mark it as that element.

2. All material things in the universe known to our senses are composed of atoms of CHEMICAL ELEMENTS.

3. Substances composed of more than one element are known as COMPOUNDS. Atoms attract and hold each other by electrical forces.

4. The smallest theoretical unit of a compound, composed of two or more atoms, is known as a MOLECULE; some elements are also normally found as molecules or crystals.

5. The smallest actual units of crystalline compounds found by use of microscopes and electron microscopes seem to be structures built up of the different atoms alternating in three-dimensional patterns to form the CRYSTAL LATTICE.

6. There were believed to be 92 CHEMICAL ELEMENTS, from hydrogen $_1H^1$, the lightest, to uranium, $_{92}U^{238}$, the heaviest, before the discovery of nuclear fission.

7. Two new elements, NEPTUNIUM, $_{93}Np^{239}$, formed by the neutron bombardment of uranium 238, and PLUTONIUM, $_{94}Pu^{238}$, formed by deuteron bombardment of uranium 238, were discovered two years thereafter.

8. Additional new elements have since been created by atomic bombardment, using the cores of light elements as projectiles. As of 1960, elements through 102 have been added, the ones beyond plutonium being: AMERICIUM, CURIUM, BERKELIUM, CALIFORNIUM, EINSTEINIUM, FERMIUM, MENDELEVIUM, and element 102.

9. When elements are represented, as above, by their chemical symbols, the subscript number is the ATOMIC NUMBER. This is different for each element. The superscript number is the MASS NUMBER, and also the total number of protons plus neutrons, or the ATOMIC WEIGHT rounded off to the nearest whole number.

10. All atoms are composed of standard interchangeable parts. These are PROTONS, NEUTRONS and ELECTRONS.

11. Protons and neutrons make up the NUCLEUS of the atom. Collectively, they are called NUCLEONS. The structure of the atom is comparable to that of the solar system. The nucleus corresponds to the sun at the center. The planets are electrons.

12. The ELECTRONS, light in weight and some distance away from the nucleus of the atom, revolve around the nucleus. They are held in their courses by electric attraction.

13. The proton has a POSITIVE charge of electricity, the electron has a NEGATIVE charge equal and opposite to the positive charge of the proton. The neutron has no charge at all.

14. The proton and the neutron each have a mass of about one ATOMIC MASS UNIT. Each is about 1800 times heavier than the electron.

15. ATOMIC NUMBER is the measure of the electric charge on, or number of protons in, the nucleus of the atom.

16. The difference in CHEMICAL PROPERTIES of the elements is caused by difference in the number of electrons, which in turn is caused by difference in the number of protons in the nucleus. The number of electrons is equal to the number of protons in an electrically neutral atom.

17. Chemical VALENCE, or combining power, is governed primarily by the electrons in the outermost orbits of each atom. Characteristics of transition elements are also governed by electrons in the next-to-outermost shell.

18. MASS NUMBER is the total number of protons and neutrons in the nucleus.

19. ATOMIC WEIGHT is the measure of the atom's mass.

20. Different atoms of the SAME ELEMENT are sometimes found to have DIFFERENT ATOMIC WEIGHTS. Such atoms are called ISOTOPES.

21. In all other ways ISOTOPES are chemical twins, alike except for weight. They have the same ATOMIC NUMBER, but have different numbers of neutrons.

22. Every element has been found to have a number of isotopes, some STABLE, some RADIOACTIVE.

23. Atomic weights of individual ISOTOPES are usually given relative to the most abundant isotope of oxygen, $_8O^{16}$, taken as 16.00000 atomic mass units (physicists' scale).

24. There are two scales of ATOMIC WEIGHTS, physical and chemical. In the physical atomic weight scale, the mass of an atom of O^{16} is used as the standard and assigned a mass of 16.00000 units. In the chemical atomic weight scale, the atomic weight of the natural isotopic mixture of oxygen, which contains O^{17} and O^{18} in addition to O^{16}, is assigned the value of 16.00000.

25. Different elements, quite distinct in chemical behavior, may have isotopes of the same atomic weight. There are $_{92}U^{238}$, $_{93}Np^{238}$, $_{94}Pu^{238}$, $_{95}Am^{238}$ and $_{96}Cm^{238}$, all with different properties. Such atoms are called ISOBARS.

26. It is the NEUTRON which figures in the transmutations that give atomic power from uranium. Neutrons can PENETRATE to the nucleus of heavy atoms when charged particles would be repelled by charges in the atom. The neutron is absorbed by the nucleus to form a heavier nucleus that is frequently unstable. If it is unstable, it then decomposes radioactively, usually emitting an electron and changing to a different element one atomic number greater.

27. The HYDROGEN atom, $_1H^1$, has just one proton as its nucleus, with one electron circling around it. Hydrogen's atomic weight and atomic number are each one.

28. Hydrogen has a rare istotope, $_1H^2$, that is just like ordinary hydrogen except it is twice as heavy. It is known as "heavy hydrogen" and sometimes as DEUTERIUM (Symbol: D). Its compound with oxygen is called "heavy water."

29. The nucleus of DEUTERIUM, called a DEUTERON, contains one proton and one neutron. The atomic number of heavy hydrogen is one, corresponding to one proton. The atomic weight is two, corresponding to the two heavy particles, proton and neutron. A third form of hydrogen, the radioactive isotope TRITIUM, $_1H^3$, is composed of one proton and two neutrons.

30. HELIUM, $_2He^4$, has two protons and two neutrons in its nucleus. The two protons correspond to helium's atomic number two. The combined weights of protons and neutrons in the nucleus give helium its atomic weight four. Two electrons, held in their orbits by the two protons, revolve around the nucleus.

31. Helium 4 at temperatures near absolute zero is a liquid with most remarkable properties and is the only known SUPERFLUID.

32. Helium also has a rare lighter isotope, $_2He^3$, composed of two protons and one neutron.

33. Uranium has a number of isotopes. The most abundant, whose atomic weight is 238, was used to produce the new elements. U-235 was used to make the ATOMIC BOMB.

34. The isotope U-235 and the element plutonium can be used for bombs because they are capable of FISSION after absorbing a neutron.

35. When fission occurs, the nucleus of the atom SPLITS into two (occasionally more) lighter elements, with release of nuclear energy.

36. In some recent experiments with high-powered cyclotrons, even more thorough fragmentation of atomic nuclei resulted. This process, resulting in many light elements, was named SPALLATION. General laws are now known that explain the processes by which atoms and nuclear particles unite and divide to form isotopes of particular mass, form and radioactive lifetimes.

37. FUSION, the process by which stars obtain their energy, is a nuclear reaction in which light nuclei combine to form a nucleus of a higher mass number, releasing large amounts of energy. The process can be said to be the opposite of nuclear fission. Fusion forms the basis of the hydrogen bomb. The possibility that the virtually limitless fuel locked as forms of hydrogen in the world's ocean can be tapped by the controlled release of fusion is under extensive investigation throughout the world.

38. MESONS are short-lived particles intermediate in mass between electrons and nucleons. HYPERONS are particles intermediate in mass between nucleons and deuterons. Their role in holding particles together in the atomic nucleus is being investigated.

39. The VOLUME of an atom is determined by the orbits of its outermost revolving electrons. Only a small fraction of the size of an atom is actually occupied by the protons, neutrons and electrons, somewhat as the space occupied by the sun, the earth and other planets is only a small part of our solar system.

40. In spite of all the unoccupied space, an atom is quite IMPENETRABLE to other atoms and to larger bodies. The electrons revolve millions of times a second, and keep everything out of the space within quite as effectively as though they were everywhere at once.

41. The things that can get inside an atom easily are protons, neutrons or electrons and fragments of other atoms. They must be shot with sufficient SPEED.

42. RADIATION is wave motion, known to us as the electromagnetic waves used for radio transmission, heat, light, X-rays, gamma rays, and as beams of atomic particles. Extremely tiny particles act like waves.

43. Three types of rays are given off by radioactive substances. ALPHA particles are high-speed nuclei of helium atoms. BETA particles are high-speed electrons. GAMMA RAYS are electromagnetic radiations similar to X-rays and light.

44. Of these, only the gamma rays used to be called radiation, and even these act very much like particles because of their short wavelength. Such a "particle" or quantum of electromagnetic radiation is called a PHOTON.

45. All atoms, when excited by high temperatures or by electric discharge, may emit light rays. These light rays, sorted according to wavelength with spectrographs, make up the SPECTRA characteristic of the elements. Most of our information about the outer structure of atoms is derived from these spectra.

46. Electrically charged particles, such as electrons, may be bent out of their straight-line paths by the influence of a magnet. This principle is used in the construction of the CYCLOTRON.

47. POSITRONS are like electrons, but are bent in the opposite direction because their charges are positive instead of negative. Thus a positron is an "anti-electron."

48. Scientists now know that atomic particles as well as mesons and hyperons have so-called "anti" forms, which denote another particle with most of the same characteristics but differ-

ing in others, including charge and magnetic moment. When normal matter collides with ANTI-MATTER, both are annihilated and tremendous amounts of energy are released.

49. The kind of rays emitted and the HALF LIFE (the time in which half the radioactivity decays) are constant characteristics of each radioactive isotope, and are used to identify that isotope.

50. In general, the gamma rays are very PENETRATING, beta rays less so, and alpha particles are easily stopped. Even though the alpha and beta rays are not very penetrating, they have enormous speed.

51. ENERGY is capacity to do work. It is work stored up for future use.

52. If you raise a weight to a height above the ground and suspend it there by some device, the WORK you put into raising it can be stored there indefinitely as POTENTIAL ENERGY. It will be there, ready, whenever you decide to release it.

53. The energy that a moving body has because it is in motion is called KINETIC ENERGY. The kinetic energy of any particle depends upon its mass and its velocity. When the moving particle strikes an object, work is done.

54. Particles of atomic size have kinetic energy arising from several different kinds of MOTION. All atoms are constantly in motion.

55. If the atoms are so dispersed that the material constituting them is a GAS, that gas will exert pressure on all sides of the container holding it, because of the motion of the gas molecules.

56. Atoms composing an element that will combine readily with another element, as hydrogen or carbon will combine with oxygen, have incomplete arrangements of the outer electrons in their systems. These incomplete arrangements allow CHEMICAL COMBINATION to take place when elements with suitable combining powers are brought together.

57. When chemical reactions occur, energy can be absorbed or released in the process. Reactions in which energy is absorbed are called ENDOTHERMIC REACTIONS; those in which energy is released are called EXOTHERMIC REACTIONS.

58. Chemical energy, electricity and heat are all forms of ENERGY. Potential and kinetic energy may be distinguished in each case.

59. These energies all arise from motion of the atom as a whole, or motion resulting from attractions and repulsions between the outer ELECTRONS of the atom's structure.

60. Energy resulting from changes in the nucleus of the atom was unknown until the discovery of RADIOACTIVITY.

61. Radioactive isotopes undergo SPONTANEOUS breaking up of their nuclei, giving off beta, alpha or gamma radiation. Loss of these particles causes the radioactive isotopes to change into isotopes of other elements.

62. The energies shown in these TRANSMUTATIONS are millions of times greater than the kinetic energies the molecules of a gas have by reason of their motion when heated. They are about a million times greater than the energy changes per atom in chemical reactions.

63. The property of matter that connects it with motion is INERTIA. Inertia is resistance to change of motion and is the measure of the MASS of an object.

64. One conclusion that appeared early in the development of the theory of RELATIVITY is that the mass of a moving body increases as its speed is increased.

65. This increase implies an equivalence between an increase in energy of motion of a body (kinetic energy) and an increase in its MASS.

66. It is for this reason that Einstein suggested that studies of radioactivity might show the EQUIVALENCE of mass and energy.

67. Einstein's statement is that the amount of energy, E, equivalent to a mass, m, is given by the equation $E = mc^2$, where c is the VELOCITY OF LIGHT.

68. From this equation, one kilogram (2.2 pounds) of matter, if CONVERTED entirely into energy, would give 25 billion kilowatt hours of energy.

69. The heat produced by BURNING one kilogram of coal is 8.5 kilowatt hours of energy.

70. Two axioms of physics state: (1) MATTER can be neither created nor destroyed; (2) ENERGY can be neither created nor destroyed. For all practical purposes they were true and separate principles until about 1940.

71. It is now known that they are, in fact, TWO PHASES of a single principle, for we have discovered that energy may sometimes be converted into matter and matter into energy.

72. Such conversion is observed in the phenomenon of nuclear FISSION, a process in which atomic nuclei split into fragments with the release of an enormous amount of energy.

73. The extreme size of the CONVERSION FACTOR explains why the equivalence of mass and energy is never observed in ordinary chemical combustion.

74. We now believe the heat given off in chemical COMBUSTION has mass associated with it, but this mass is so small it cannot be detected by the most sensitive balances available.

75. From the standpoint of the Laws of the Conservation of Matter and of Energy alone, transformation of matter into energy results in the DESTRUCTION of matter and CREATION of energy.

(Compiled originally by Helen M. Davis; revised 1960.)

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TECHNOLOGY

TV Helps Mine Recovery

➤ AN UNDERWATER TELEVISION camera is helping the Navy to recover valuable ordnance units from the ocean floor at depths where divers cannot safely operate.

The camera guides a 12-ton shipboard crane in quickly retrieving air-dropped or submarine-laid mines from a test area of the Naval Ordnance Laboratory Test Facility at Fort Lauderdale. The area is three miles off-shore.

The mines under test are developed by the Naval Ordnance Laboratory, White Oak, Silver Spring, Md., and then sent to the NOLTF at Fort Lauderdale for full-scale sea trials.

When mines are planted, their location is pinpointed by two spotting towers situated about three miles apart on the beach. This information is relayed to a recovery ship that anchors directly over the area and lowers the camera assembly to search the ocean floor.

Once on the bottom, the TV unit rotates in a full 360-degree circle and scans from the ocean floor beneath the camera assembly to almost directly above it in a 100-degree arc. Objects more than 75 feet away at 360-foot depths can be spotted by the camera's wide-angle lens under good natural light conditions. Natural light is preferable to artificial light because the tiny plankton life in the seawater reflects artificial light, clouding the TV picture.

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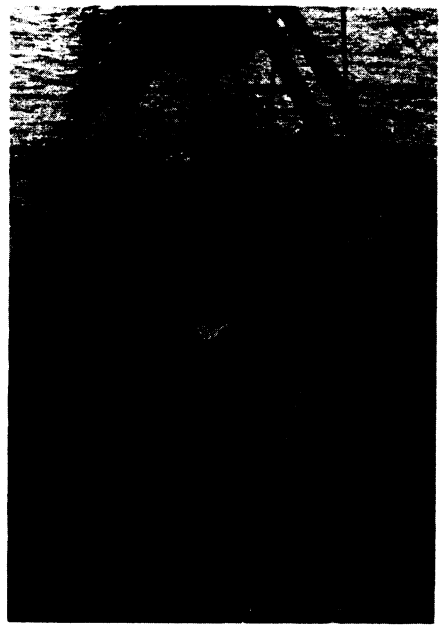

RECOVERED MINE—Guided by an underwater television camera, a 12-ton crane on a U. S. Naval Ordnance Laboratory recovery ship hauls up a mine in a clamshell bucket near Fort Lauderdale, Fla. The mine was spotted in 360 feet of water.

RADIO ASTRONOMY

New Method Found for Large Radio Telescopes

➤ A LARGE RADIO TELESCOPE can be made by mathematically combining the radio information received on two smaller radio telescopes. This new method has been developed by two astronomers at the Cavendish Laboratory in Cambridge, England.

Drs. M. Ryle and A. Hewish devised the synthetic radio telescope to obtain increased resolving power. Many investigations of the sources of radio waves in the heavens are limited by the resolving power that can be achieved by conventional methods of constructing the receiving antennas.

To overcome such limitations, Drs. Ryle and Hewish developed a method by which two antennas are so arranged that their relative positions can be altered to occupy successively the whole area of a much larger equivalent aerial.

The results of such observations are then combined mathematically, they report in the Monthly Notices of the Royal Astronomical Society, 120:220, 1960, published in London.

The new method of obtaining increased resolving power can be applied to both "pencil beam" systems and interferometers. An interferometric system designed for the study of radio sources has been built with an equivalent area for resolution of 800,000 square feet.

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