

CHEMICAL FORMULA FOR SUGAR

CHEMICAL FORMULA FOR SUGAR IS A FUNDAMENTAL CONCEPT IN UNDERSTANDING THE BUILDING BLOCKS OF SWEET TASTES AND THE ENERGY SOURCES THAT FUEL LIFE. WHILE COMMONLY REFERRED TO AS "SUGAR," THIS TERM ENCOMPASSES A DIVERSE FAMILY OF CARBOHYDRATES, EACH WITH ITS OWN UNIQUE CHEMICAL STRUCTURE. THIS ARTICLE WILL DELVE DEEP INTO THE CHEMICAL FORMULAS THAT DEFINE VARIOUS SUGARS, EXPLORING THE DISTINCTIONS BETWEEN SIMPLE AND COMPLEX CARBOHYDRATES, THE ROLE OF MONOSACCHARIDES AND DISACCHARIDES, AND THE SIGNIFICANCE OF THESE MOLECULAR ARRANGEMENTS IN BIOLOGY AND INDUSTRY. WE WILL UNRAVEL THE CORE COMPONENTS THAT MAKE UP THESE SWEET MOLECULES, PROVIDING A COMPREHENSIVE OVERVIEW FOR ANYONE SEEKING TO UNDERSTAND THE CHEMISTRY BEHIND SWEETNESS.

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UNDERSTANDING CARBOHYDRATES

CARBOHYDRATES ARE ONE OF THE THREE MACRONUTRIENTS FOUND IN FOOD, ALONGSIDE PROTEINS AND FATS. THEY ARE ORGANIC COMPOUNDS COMPOSED OF CARBON, HYDROGEN, AND OXYGEN, WITH THE GENERAL EMPIRICAL FORMULA $(CH_2O)_n$. THIS FORMULA SUGGESTS THAT FOR EVERY CARBON ATOM, THERE IS GENERALLY A MOLECULE OF WATER. CARBOHYDRATES ARE ESSENTIAL FOR PROVIDING ENERGY TO THE BODY, SERVING AS A PRIMARY FUEL SOURCE FOR CELLS, TISSUES, AND ORGANS.

THE CLASSIFICATION OF CARBOHYDRATES IS LARGELY BASED ON THEIR MOLECULAR SIZE AND STRUCTURE, WHICH DIRECTLY RELATES TO THEIR CHEMICAL FORMULA. SIMPLE CARBOHYDRATES, SUCH AS MONOSACCHARIDES AND DISACCHARIDES, ARE READILY ABSORBED BY THE BODY AND PROVIDE QUICK ENERGY. COMPLEX CARBOHYDRATES, OR POLYSACCHARIDES, ARE COMPOSED OF LONG CHAINS OF MONOSACCHARIDE UNITS AND ARE DIGESTED MORE SLOWLY, OFFERING A SUSTAINED RELEASE OF ENERGY AND OFTEN PROVIDING DIETARY FIBER.

MONOSACCHARIDES: THE SIMPLEST SUGARS

MONOSACCHARIDES ARE THE SIMPLEST FORM OF CARBOHYDRATES, MEANING THEY CANNOT BE BROKEN DOWN INTO SIMPLER SUGARS BY HYDROLYSIS. THEY ARE THE BASIC BUILDING BLOCKS FROM WHICH ALL OTHER CARBOHYDRATES ARE CONSTRUCTED. THE MOST COMMON MONOSACCHARIDES CONTAIN EITHER FIVE CARBON ATOMS (PENTOSES) OR SIX CARBON ATOMS (HEXOSES).

HEXOSES: THE SIX-CARBON SUGARS

HEXOSES ARE THE MOST PREVALENT AND SIGNIFICANT MONOSACCHARIDES IN BIOLOGICAL SYSTEMS. THEIR CHEMICAL FORMULA IS $C_6H_{12}O_6$. DESPITE SHARING THE SAME MOLECULAR FORMULA, HEXOSES CAN EXIST AS DIFFERENT STRUCTURAL ISOMERS, MEANING THEY HAVE THE SAME ATOMS ARRANGED IN DIFFERENT WAYS, LEADING TO DISTINCT PROPERTIES. THE THREE MOST IMPORTANT HEXOSES ARE GLUCOSE, FRUCTOSE, AND GALACTOSE.

- **GLUCOSE:** OFTEN REFERRED TO AS BLOOD SUGAR, GLUCOSE IS THE PRIMARY SOURCE OF ENERGY FOR MOST LIVING ORGANISMS. IT IS A KEY PRODUCT OF PHOTOSYNTHESIS AND IS CENTRAL TO CELLULAR RESPIRATION.

- **FRUCTOSE:** KNOWN AS FRUIT SUGAR, FRUCTOSE IS FOUND IN FRUITS, HONEY, AND ROOT VEGETABLES. IT IS SWEETER THAN GLUCOSE AND IS OFTEN USED AS A SWEETENER IN FOOD PRODUCTS.
- **GALACTOSE:** GALACTOSE IS A CONSTITUENT OF LACTOSE, THE SUGAR FOUND IN MILK. IT PLAYS A ROLE IN THE SYNTHESIS OF GLYCOPROTEINS AND GLYCOLIPIDS.

PENTOSE: THE FIVE-CARBON SUGARS

PENTOSE ARE MONOSACCHARIDES CONTAINING FIVE CARBON ATOMS, WITH THE CHEMICAL FORMULA $C_5H_{10}O_5$. WHILE LESS COMMON AS DIETARY SUGARS THAN HEXOSES, THEY ARE VITAL COMPONENTS OF NUCLEIC ACIDS (DNA AND RNA) AND OTHER IMPORTANT BIOLOGICAL MOLECULES. RIBOSE (A COMPONENT OF RNA AND ATP) AND DEOXYRIBOSE (A COMPONENT OF DNA) ARE KEY EXAMPLES OF PENTOSE.

DISACCHARIDES: TWO MONOSACCHARIDES COMBINED

DISACCHARIDES ARE CARBOHYDRATES FORMED WHEN TWO MONOSACCHARIDE UNITS ARE LINKED TOGETHER BY A GLYCOSIDIC BOND THROUGH A DEHYDRATION REACTION, WHERE A MOLECULE OF WATER IS REMOVED. THEIR GENERAL CHEMICAL FORMULA IS $C_{12}H_{22}O_{11}$. LIKE MONOSACCHARIDES, DISACCHARIDES CAN EXHIBIT DIFFERENT PROPERTIES BASED ON THE SPECIFIC MONOSACCHARIDES THAT COMPOSE THEM.

SUCROSE: TABLE SUGAR

SUCROSE, COMMONLY KNOWN AS TABLE SUGAR, IS PERHAPS THE MOST FAMILIAR DISACCHARIDE. IT IS COMPOSED OF ONE MOLECULE OF GLUCOSE AND ONE MOLECULE OF FRUCTOSE JOINED BY AN α, β -1,2 GLYCOSIDIC BOND. THIS COMBINATION IS WHAT GIVES SUCROSE ITS CHARACTERISTIC SWEET TASTE AND MAKES IT A WIDELY USED SWEETENER IN FOOD AND BEVERAGES. ITS CHEMICAL FORMULA IS $C_{12}H_{22}O_{11}$.

LACTOSE: MILK SUGAR

LACTOSE IS THE PRIMARY CARBOHYDRATE FOUND IN MILK AND DAIRY PRODUCTS. IT IS A DISACCHARIDE FORMED FROM ONE MOLECULE OF GLUCOSE AND ONE MOLECULE OF GALACTOSE, LINKED BY A β -1,4 GLYCOSIDIC BOND. LACTOSE IS LESS SWEET THAN SUCROSE AND IS BROKEN DOWN BY THE ENZYME LACTASE IN THE DIGESTIVE SYSTEM. THE CHEMICAL FORMULA FOR LACTOSE IS ALSO $C_{12}H_{22}O_{11}$.

MALTOSE: MALT SUGAR

MALTOSE, ALSO KNOWN AS MALT SUGAR, IS COMPOSED OF TWO GLUCOSE UNITS LINKED BY AN α -1,4 GLYCOSIDIC BOND. IT IS PRODUCED DURING THE GERMINATION OF SEEDS AND IS AN INTERMEDIATE PRODUCT IN THE DIGESTION OF STARCH. ITS CHEMICAL FORMULA IS $C_{12}H_{22}O_{11}$.

POLYSACCHARIDES: COMPLEX CARBOHYDRATES

POLYSACCHARIDES ARE COMPLEX CARBOHYDRATES MADE UP OF LONG CHAINS OF MONOSACCHARIDE UNITS, OFTEN THOUSANDS OF THEM, LINKED TOGETHER. THEIR CHEMICAL FORMULAS ARE MUCH MORE COMPLEX AND VARIABLE, DEPENDING ON THE NUMBER OF MONOSACCHARIDE UNITS AND THEIR ARRANGEMENT. POLYSACCHARIDES SERVE AS ENERGY STORAGE MOLECULES OR STRUCTURAL COMPONENTS IN LIVING ORGANISMS.

STARCH: ENERGY STORAGE IN PLANTS

STARCH IS THE PRIMARY ENERGY STORAGE POLYSACCHARIDE IN PLANTS. IT IS COMPOSED OF REPEATING GLUCOSE UNITS AND EXISTS IN TWO FORMS: AMYLOSE (A LINEAR CHAIN) AND AMYLOPECTIN (A BRANCHED CHAIN). STARCH IS A SIGNIFICANT DIETARY COMPONENT FOR HUMANS, PROVIDING A SLOWER RELEASE OF GLUCOSE COMPARED TO SIMPLE SUGARS. THE GENERAL FORMULA FOR STARCH CAN BE REPRESENTED AS $(C_6H_{10}O_5)_n$, WHERE 'n' REPRESENTS A LARGE NUMBER OF GLUCOSE UNITS.

GLYCOGEN: ENERGY STORAGE IN ANIMALS

GLYCOGEN IS THE ANIMAL EQUIVALENT OF STARCH AND IS THE PRIMARY FORM OF GLUCOSE STORAGE IN ANIMALS AND FUNGI. IT IS STORED MAINLY IN THE LIVER AND MUSCLES. GLYCOGEN IS A HIGHLY BRANCHED POLYSACCHARIDE, ALLOWING FOR RAPID RELEASE OF GLUCOSE WHEN ENERGY IS NEEDED. ITS GENERAL FORMULA IS ALSO REPRESENTED AS $(C_6H_{10}O_5)_n$.

CELLULOSE: STRUCTURAL SUPPORT

CELLULOSE IS A STRUCTURAL POLYSACCHARIDE THAT FORMS THE MAIN COMPONENT OF THE CELL WALLS OF PLANTS. IT IS COMPOSED OF REPEATING GLUCOSE UNITS LINKED BY β -1,4 GLYCOSIDIC BONDS. WHILE ABUNDANT IN NATURE, CELLULOSE IS INDIGESTIBLE BY HUMANS AND MOST ANIMALS, SERVING AS DIETARY FIBER. ITS GENERAL FORMULA IS $(C_6H_{10}O_5)_n$.

THE CHEMICAL FORMULA FOR COMMON TABLE SUGAR

AS PREVIOUSLY MENTIONED, THE COMMON TABLE SUGAR THAT WE USE IN OUR KITCHENS IS CHEMICALLY KNOWN AS SUCROSE. THE PRECISE CHEMICAL FORMULA FOR SUCROSE IS $C_{12}H_{22}O_{11}$. THIS FORMULA INDICATES THAT EACH MOLECULE OF SUCROSE CONTAINS 12 CARBON ATOMS, 22 HYDROGEN ATOMS, AND 11 OXYGEN ATOMS. THIS ARRANGEMENT IS A RESULT OF THE COVALENT BONDING BETWEEN A GLUCOSE MOLECULE ($C_6H_{12}O_6$) AND A FRUCTOSE MOLECULE ($C_6H_{12}O_6$) WITH THE ELIMINATION OF ONE WATER MOLECULE (H_2O) DURING THE GLYCOSIDIC BOND FORMATION.

THE EMPIRICAL FORMULA FOR SUCROSE, AND INDEED FOR MOST SIMPLE SUGARS AND DISACCHARIDES, IS CH_2O , REPRESENTING THE RATIO OF CARBON, HYDROGEN, AND OXYGEN. HOWEVER, THE MOLECULAR FORMULA, $C_{12}H_{22}O_{11}$, PROVIDES THE ACTUAL NUMBER OF ATOMS OF EACH ELEMENT PRESENT IN A SINGLE MOLECULE, WHICH IS CRUCIAL FOR UNDERSTANDING ITS CHEMICAL REACTIONS AND PROPERTIES.

BEYOND GLUCOSE: OTHER IMPORTANT SUGARS

WHILE GLUCOSE AND FRUCTOSE ARE PERHAPS THE MOST WIDELY RECOGNIZED SIMPLE SUGARS DUE TO THEIR ROLES IN ENERGY METABOLISM AND TASTE, THE WORLD OF SUGARS IS VAST AND COMPLEX. MANY OTHER MONOSACCHARIDES AND DISACCHARIDES PLAY CRITICAL ROLES IN BIOLOGICAL PROCESSES OR HAVE INDUSTRIAL APPLICATIONS. FOR INSTANCE, MANNOSE IS ANOTHER

HEXOSE THAT IS A COMPONENT OF VARIOUS GLYCOPROTEINS. MANNITOL IS A SUGAR ALCOHOL DERIVED FROM MANNOSE, OFTEN USED AS A SWEETENER AND A LAXATIVE.

IN THE REALM OF DISACCHARIDES, TREHALOSE IS A NON-REDUCING SUGAR COMPOSED OF TWO GLUCOSE UNITS LINKED BY AN $\alpha(1\rightarrow1)\beta$ GLYCOSIDIC BOND. IT IS FOUND IN INSECTS AND SOME PLANTS AND IS KNOWN FOR ITS ABILITY TO PROTECT BIOLOGICAL MOLECULES FROM DAMAGE CAUSED BY DEHYDRATION OR FREEZING. EACH OF THESE SUGARS, DESPITE THEIR STRUCTURAL SIMILARITIES, POSSESSES A UNIQUE CHEMICAL FORMULA THAT DICTATES THEIR SPECIFIC FUNCTION AND INTERACTIONS.

IMPORTANCE OF SUGAR FORMULAS IN SCIENCE AND INDUSTRY

THE PRECISE CHEMICAL FORMULA FOR SUGAR, WHETHER IT BE GLUCOSE ($C_6H_{12}O_6$), FRUCTOSE ($C_6H_{12}O_6$), OR SUCROSE ($C_{12}H_{22}O_{11}$), IS PARAMOUNT IN NUMEROUS SCIENTIFIC AND INDUSTRIAL APPLICATIONS. IN BIOCHEMISTRY AND MEDICINE, UNDERSTANDING THESE FORMULAS IS KEY TO COMPREHENDING METABOLIC PATHWAYS, THE REGULATION OF BLOOD GLUCOSE LEVELS, AND THE DEVELOPMENT OF TREATMENTS FOR METABOLIC DISORDERS LIKE DIABETES.

IN THE FOOD INDUSTRY, KNOWLEDGE OF SUGAR FORMULAS INFLUENCES PRODUCT DEVELOPMENT, SHELF-LIFE STABILITY, AND SWEETNESS PROFILES. FOR EXAMPLE, THE DIFFERING SWEETNESS LEVELS OF GLUCOSE, FRUCTOSE, AND SUCROSE DIRECTLY IMPACT HOW MUCH OF EACH IS USED TO ACHIEVE A DESIRED TASTE. FURTHERMORE, THE CHEMICAL REACTIVITY DICTATED BY THESE FORMULAS AFFECTS PROCESSES LIKE CARAMELIZATION AND FERMENTATION. IN AGRICULTURE, UNDERSTANDING THE SYNTHESIS OF SUGARS THROUGH PHOTOSYNTHESIS RELIES HEAVILY ON THE CHEMICAL FORMULAS OF THE MOLECULES INVOLVED.

CHEMICAL REACTIONS AND PROPERTIES

THE CHEMICAL FORMULA OF A SUGAR DIRECTLY DICTATES ITS CHEMICAL BEHAVIOR. THE PRESENCE AND ARRANGEMENT OF HYDROXYL ($-OH$) GROUPS AND CARBONYL ($C=O$) GROUPS ON THE CARBON SKELETON DETERMINE WHETHER A SUGAR IS AN ALDOSE (CONTAINING AN ALDEHYDE GROUP) OR A KETOSE (CONTAINING A KETONE GROUP). THIS CLASSIFICATION INFLUENCES THEIR REACTIVITY IN VARIOUS CHEMICAL TESTS AND BIOLOGICAL PROCESSES.

FOR INSTANCE, THE PRESENCE OF A FREE CARBONYL GROUP IN REDUCING SUGARS LIKE GLUCOSE ALLOWS THEM TO ACT AS REDUCING AGENTS, A PROPERTY EXPLOITED IN BENEDICT'S TEST. NON-REDUCING SUGARS, LIKE SUCROSE, WHERE THE CARBONYL CARBONS ARE INVOLVED IN THE GLYCOSIDIC BOND, DO NOT EXHIBIT THIS REDUCING PROPERTY. THESE DISTINCTIONS ARE CRITICAL FOR ANALYTICAL CHEMISTRY AND QUALITY CONTROL IN FOOD PRODUCTION.

NUTRITIONAL AND HEALTH IMPLICATIONS

THE CHEMICAL STRUCTURE, AS REPRESENTED BY THE CHEMICAL FORMULA, HAS PROFOUND IMPLICATIONS FOR HOW SUGARS ARE PROCESSED BY THE HUMAN BODY AND THEIR IMPACT ON HEALTH. SIMPLE SUGARS LIKE GLUCOSE AND FRUCTOSE ARE QUICKLY ABSORBED AND CAN LEAD TO RAPID SPIKES IN BLOOD GLUCOSE. WHILE GLUCOSE IS ESSENTIAL FOR IMMEDIATE ENERGY, EXCESSIVE INTAKE OF ANY SUGAR CAN CONTRIBUTE TO HEALTH ISSUES. COMPLEX CARBOHYDRATES, WITH THEIR LONG CHAINS OF MONOSACCHARIDES, ARE DIGESTED MORE SLOWLY, PROVIDING A MORE SUSTAINED ENERGY RELEASE AND OFTEN CONTRIBUTING BENEFICIAL FIBER TO THE DIET.

UNDERSTANDING THE SPECIFIC SUGAR FORMULAS HELPS IN IDENTIFYING AND MANAGING DIETARY RECOMMENDATIONS. FOR INSTANCE, KNOWING THAT LACTOSE IS COMPOSED OF GLUCOSE AND GALACTOSE IS IMPORTANT FOR INDIVIDUALS WITH LACTOSE INTOLERANCE, AS THEY LACK THE ENZYME TO BREAK DOWN THIS PARTICULAR DISACCHARIDE.

FAQ SECTION

Q: WHAT IS THE MOST COMMON CHEMICAL FORMULA FOR SUGAR?

A: THE MOST COMMON AND BASIC CHEMICAL FORMULA FOR SIMPLE SUGARS (MONOSACCHARIDES) LIKE GLUCOSE AND FRUCTOSE IS $C_6H_{12}O_6$. FOR DISACCHARIDES LIKE SUCROSE, WHICH IS COMMON TABLE SUGAR, THE FORMULA IS $C_{12}H_{22}O_{11}$.

Q: IS THE CHEMICAL FORMULA FOR ALL SUGARS THE SAME?

A: NO, THE CHEMICAL FORMULA FOR ALL SUGARS IS NOT THE SAME. WHILE SIMPLE SUGARS (MONOSACCHARIDES) OFTEN SHARE THE SAME MOLECULAR FORMULA LIKE $C_6H_{12}O_6$, THEY CAN BE STRUCTURAL ISOMERS WITH DIFFERENT ARRANGEMENTS OF ATOMS. DISACCHARIDES (LIKE SUCROSE, LACTOSE, AND MALTOSE) HAVE THE MOLECULAR FORMULA $C_{12}H_{22}O_{11}$, AND POLYSACCHARIDES (LIKE STARCH AND CELLULOSE) HAVE MUCH MORE COMPLEX AND VARIABLE FORMULAS REPRESENTED GENERALLY AS $(C_6H_{10}O_5)_N$.

Q: WHAT DOES THE CHEMICAL FORMULA $C_6H_{12}O_6$ REPRESENT?

A: THE CHEMICAL FORMULA $C_6H_{12}O_6$ REPRESENTS A MONOSACCHARIDE, SPECIFICALLY A HEXOSE. THIS FORMULA IS SHARED BY IMPORTANT SUGARS LIKE GLUCOSE (BLOOD SUGAR), FRUCTOSE (FRUIT SUGAR), AND GALACTOSE (PART OF MILK SUGAR). IT INDICATES THAT EACH MOLECULE CONTAINS 6 CARBON ATOMS, 12 HYDROGEN ATOMS, AND 6 OXYGEN ATOMS.

Q: HOW IS THE CHEMICAL FORMULA FOR TABLE SUGAR (SUCROSE) DERIVED?

A: TABLE SUGAR, OR SUCROSE, IS A DISACCHARIDE FORMED FROM ONE MOLECULE OF GLUCOSE ($C_6H_{12}O_6$) AND ONE MOLECULE OF FRUCTOSE ($C_6H_{12}O_6$) JOINED BY A GLYCOSIDIC BOND. THIS PROCESS RELEASES ONE MOLECULE OF WATER (H_2O). THEREFORE, THE FORMULA FOR SUCROSE IS $(C_6H_{12}O_6 + C_6H_{12}O_6) - H_2O$, WHICH SIMPLIFIES TO $C_{12}H_{22}O_{11}$.

Q: ARE STARCH AND TABLE SUGAR MADE OF THE SAME BASIC CHEMICAL UNITS?

A: YES, BOTH STARCH AND TABLE SUGAR ARE CARBOHYDRATES MADE OF REPEATING UNITS OF GLUCOSE. HOWEVER, STARCH IS A POLYSACCHARIDE, MEANING IT IS A LONG CHAIN OF MANY GLUCOSE UNITS (REPRESENTED AS $(C_6H_{10}O_5)_N$), WHILE TABLE SUGAR (SUCROSE) IS A DISACCHARIDE MADE OF JUST TWO GLUCOSE UNITS LINKED TO A FRUCTOSE MOLECULE, WITH THE FORMULA $C_{12}H_{22}O_{11}$.

Q: WHAT IS THE DIFFERENCE BETWEEN THE EMPIRICAL FORMULA AND THE MOLECULAR FORMULA FOR SUGAR?

A: THE EMPIRICAL FORMULA FOR SIMPLE SUGARS, LIKE GLUCOSE, IS CH_2O , REPRESENTING THE SIMPLEST WHOLE-NUMBER RATIO OF ATOMS (1 CARBON : 2 HYDROGEN : 1 OXYGEN). THE MOLECULAR FORMULA, SUCH AS $C_6H_{12}O_6$ FOR GLUCOSE, PROVIDES THE ACTUAL NUMBER OF ATOMS OF EACH ELEMENT IN A MOLECULE. THE MOLECULAR FORMULA IS MORE INFORMATIVE FOR UNDERSTANDING A COMPOUND'S PROPERTIES AND REACTIONS.

Q: DO DIFFERENT TYPES OF SUGAR HAVE DIFFERENT TASTES BECAUSE OF THEIR CHEMICAL FORMULAS?

A: WHILE THE CHEMICAL FORMULA DEFINES THE BASIC ATOMIC COMPOSITION, THE SPECIFIC ARRANGEMENT OF ATOMS (ISOMERISM) AND THE FUNCTIONAL GROUPS PRESENT, AS DICTATED BY THE FORMULA, SIGNIFICANTLY INFLUENCE TASTE. FOR EXAMPLE, GLUCOSE AND FRUCTOSE SHARE THE SAME MOLECULAR FORMULA ($C_6H_{12}O_6$) BUT ARE PERCEIVED TO HAVE DIFFERENT SWEETNESS LEVELS DUE TO THEIR STRUCTURAL DIFFERENCES. SUCROSE ($C_{12}H_{22}O_{11}$) TASTES SWEETER THAN LACTOSE ($C_{12}H_{22}O_{11}$) DUE TO ITS SPECIFIC STRUCTURE.

Q: WHY IS KNOWING THE CHEMICAL FORMULA OF SUGAR IMPORTANT IN CHEMISTRY?

A: KNOWING THE CHEMICAL FORMULA OF SUGAR IS FUNDAMENTAL IN CHEMISTRY BECAUSE IT ALLOWS CHEMISTS TO PREDICT AND UNDERSTAND ITS PROPERTIES, REACTIVITY, AND HOW IT WILL BEHAVE IN CHEMICAL REACTIONS. IT'S THE BASIS FOR UNDERSTANDING STOICHIOMETRY, REACTION MECHANISMS, AND THE SYNTHESIS OF NEW COMPOUNDS.

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