

Chapter 6

The Structure of Matter

Cmpds and Molecules

6.1

Key Ideas

- What holds a cmpd together?
- How can the structure of chemical cmpds be shown?
- What determines the properties of a cmpd?

Statue of Liberty



- What color is the statue of liberty?
- What color is a penny?
- Why is a penny copper colored?
- Why is the statue of liberty green?
- The copper has combined with some other elements producing a new compound.
- This is what we are going to learn about in this chapter.



Chemical Bonds

- *What holds a cmpd together?*
- A cmpd is a substance made of 2 or more elements bonded together
- A **chemical bond** is the force that holds a cmpd together
 - This can be applied between atoms or ions



Chemical Bonds

- Some of the matter around you is in the form of uncombined elements such as copper, sulfur, and oxygen.
- Like many other sets of elements, these three elements unite chemically to form a compound when the conditions are right.

Chemical Bonds

- The green coating on the Statue of Liberty and some old pennies is a result of this chemical change.



New Properties

- The compound formed when elements combine often has properties that aren't anything like those of the individual elements.
- Sodium chloride, for example, is a compound made from the elements sodium and chlorine.



New Properties

- Remember chlorine is a ...
- Sodium reacts violently with...
- You chemically combine them and you can put it on your ...



New Properties

- The green coating on the statue of liberty and some pennies is the result of a chemical change.
- You don't have copper anymore!
- What you have is copper sulfate.
- Copper sulfate is green in color (like the statue of liberty)



Chemical Structure

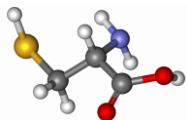
- *How can the structure of chemical cmpds be shown?*
- The structure of chemical compounds can be shown by various models. Different models show different aspects of compounds.
 - Ball and Stick, Space Filling, Structural

Chemical Structure

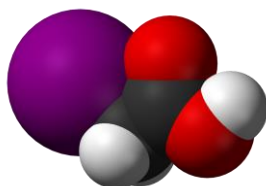
- The **Chemical Structure** is the arrangement of atoms in a cmpd
- This structure can be shown by using models!
 - Ball and Stick models use spheres to represent atoms and sticks to represent bonds
 - Structural Formulas use the element symbols instead of spheres
 - Space Filling models show the amount of "space" the atoms take up

Chemical Structures

Ball and Stick



Space Filling



Structural
H—O—H

Chemical Structure

- The bond length and bond angle is represented in some of the models.
– Which ones?
- Bond strength is determined by....
- The **bond length** is the average distance between the nuclei of two bonded atoms
- The **bond angle** is the angle formed by two bonds to the same atom

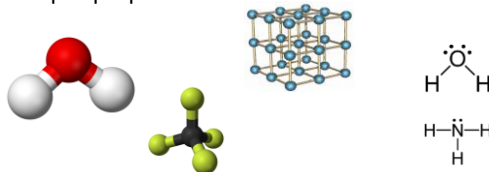


Chemical Structure

- While the models make the bonds look like a rigid connection (like a stick) they can bend, stretch, and rotate
- In fact, you can think of bonds like a flexible spring (it can bend, stretch and rotate)

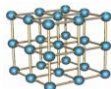
How does Structure Affect Properties

- *What determines the properties of a compd?*
- How they are bonded together impacts the compds properties



How does Structure Affect Properties

- *What determines the properties of a compd?*
- How they are bonded together impacts the compds properties
 - Compds that form a network are very strong
 - Think of lattice
 - Examples of lattice bonded compds... Salt, Sugar, things that make boxes when bonded



How does Structure Affect Properties

- Lets think about the lab at the beginning of the chapter
 - Just an FYI....Both compds had a lattice structure
 - Which compd had a lower melting point?
 - What does this mean about the bonds that were holding it together?
 - Sugar has molecular bonds while Salt has ionic bonds, which are stronger? Explain.

How does Structure Affect Properties

- So....
 - Higher melting point means _____ bonds
 - Higher boiling means _____ bonds
- Also, the state of matter can give you a clue as to bond strength.

Solid > Liquid > Gas

Quick Review

- What are the 3 cmpd models we discussed?
- Draw the 3 cmpd models we discussed.
- What holds a cmpd together?
- How can the structure of chemical cmpds be shown?
- What determines the properties of a cmpd?

Assignment

- EOSQ (1,5)
- 6.1 CR
- TON 6.2

Ionic and Covalent Bonding

6.2

Key Ideas

- Why do atoms form bonds?
- How do ionic bonds form?
- What do atoms joined by covalent bonds share?
- What gives metals their distinctive properties?
- How are polyatomic ions similar to other ions?

Why Do Chemical Bonds Form?

- Usually, atoms join to form bonds so atoms end up with a stable electron configuration.
 - Noble Gas configurations
 - 8 is great 😊
- There are 2 main types of bonding
 - Covalent
 - Ionic

Atomic Stability



- The electric forces between oppositely charged electrons and protons hold atoms and molecules together, and thus are the forces that cause compounds to form.
- Atoms of noble gases are unusually stable.
- Compounds of these atoms rarely form because they are almost always less stable than the original atoms.



Why Do Chemical Bonds Form?

| | Ionic compounds | Covalent compounds |
|----------------------------|---------------------------------|-----------------------|
| Structure | network of bonded ions | molecules |
| Valence electrons | transferred | shared |
| Electrical conductivity | good (when melted or dissolved) | poor |
| State at room temperature | solid | solid, liquid, or gas |
| Melting and boiling points | generally high | generally low |

- Does it make sense that sugar melted first?

Ionic Bonds

- *How do ionic bonds form?*
- Ionic bonds form between oppositely charged ions
- An **ionic bond** the attractive force between oppositely charged ions, which form when electrons are transferred from one atom to another

Gain or Loss of Electron(s)

- The positive and negative charges are not balanced.
- It is the electric forces between oppositely charged particles, such as ions, that hold compounds together.

A Bond Forms

- A neutral atom of sodium has one electron in its outer level. This is not a stable outer energy level.
- When sodium forms a compound with iodine, sodium loses one electron from its third level, and the second level becomes a complete outer level.



A Bond Forms

- The sodium atom has become an ion.
- When a sodium atom loses an electron, the atom becomes positively charged because there is one electron less in the atom than there are protons in the nucleus
- The 1+ charge is shown as a superscript written after the element's symbol, Na^{+1} , to indicate its charge.

A Bond Forms

- The iodine atom in this reaction undergoes change, as well.
- An iodine atom has seven electrons in its outer energy level.
- During the reaction with potassium, the iodide atom gains an electron, leaving its outer energy level with eight electrons.

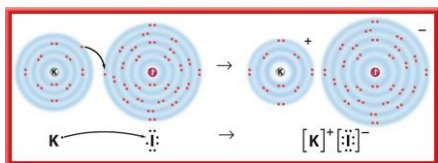
A Bond Forms

- This atom is no longer neutral because it gained an extra negative particle.
- It now has a charge of 1- (OR -1) and is called an iodide ion, written as I^{-1} .



A Bond Forms

- Notice that the resulting compound has a neutral charge because the positive and negative charges of the ions cancel each other.



To make an ion, you change the number of protons in the atom.

1. True
2. False

K^+ has a charge of...

1. 1
2. +1
3. 2
4. +2
5. -1
6. None of the above

K^+ has more electrons than protons.

1. True
2. False

Rb⁺ is the same as Rb⁺¹.

1. True
2. False

K⁺ loses 1 electron.

1. Yes
2. No

The Ionic Bond

- The result of this bond is a neutral compound.
- The compound as a whole is neutral because the sum of the charges on the ions is zero.

The Ionic Bond

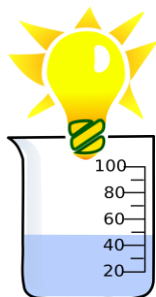
- When atoms form an ionic compound, their electrons are shifted to the other atoms, but the overall number of protons and electrons of the combined atoms remains equal and unchanged. Therefore, the compound is neutral.
- Ionic bonds usually are formed by bonding between metals and nonmetals.

Ionic Bonds

- Ionic Cmpds are found in networks
- The smallest ratio of an ionic network is called a **formula unit**
 - It is what you would've called a molecule before right now
- Ionic cmpds will conduct electricity when melted or dissolved in water

Quick Demo

- Light Bulb and water



Sharing Electrons

- The attraction that forms between atoms when they share electrons is known as a **covalent bond**.
- A neutral particle that forms as a result of electron sharing is called a **molecule**.
- These usually happen between nonmetals

Quick Example

- Board with colored circles
- Cl₂
- H₂O
- CO₂

Single Covalent Bond

- A single covalent bond is made up of two shared electrons.
- A water molecule contains two single bonds. In each bond, a hydrogen atom contributes one electron to the bond and the oxygen atom contributes the other.
- The result of this type of bonding is a stable outer energy level for each atom in the molecule.

Multiple Bonds

- A covalent bond also can contain more than one pair of electrons.
- An example of this is the bond in nitrogen (N_2).

Multiple Bonds

- A nitrogen atom has five electrons in its outer energy level and needs to gain three electrons to become stable.
- It does this by sharing its three electrons with another nitrogen atom.
- This is a triple bond.

Multiple Bonds

- When each atom contributes three electrons to the bond, the bond contains six electrons, or three pairs of electrons.
- Each pair of electrons represents a bond.
- Therefore, three pairs of electrons represent three bonds, or a triple bond.

Unequal sharing :(

- Electrons are not always shared equally between atoms in a covalent bond.
- A **polar molecule** is one that has a slightly positive end and a slightly negative end although the overall molecule is neutral. Water is an example of a polar molecule.
- A **nonpolar molecule** is one in which electrons are shared equally in bonds.

If sulfur bonds with another sulfur, it will make a ...

- A. Single bond
- B. Double bond
- C. Triple bond
- D. Ionic bond
- E. None of the above
- F. More than one of the above

Ionic bonds form by (giving and taking) of electrons between atoms.

1. True
2. False

Which of the following will most likely
from an stable ionic bond?

1. Na & K
2. Mg & He
3. Al & O
4. None of the above
5. More than one of
the above

Covalent bonds share electrons so
both elements have a full outer shell.

1. True
2. False

Unequal sharing happens b/c 1
element has a stronger attraction than
the other

1. True
2. False

The overall charge of a compound with an ionic bond is?

1. Positive
2. Negative
3. Neutral
4. None of the above

Covalent bonds share electrons.

1. True
2. False

Metallic Bonds

- *What gives metals their distinctive properties?*
- Metals are flexible and conduct electric current well because their atoms and electrons can move freely throughout a metal's packed structure.
- A **Metallic bond** is a bond formed by the attraction between positively charged metal ions and the electrons around them

Polyatomic Ions

- *How are polyatomic ions similar to other ions?*
- A polyatomic ion acts as a single unit in a compound, just as ions that consist of a single atom do.
- A **polyatomic ion** is an ion made of 2 or more atoms

Polyatomic Ions

- Polyatomic Ion Handout

Polyatomic Ions

- Sometimes the ending of the polyatomic ion name can indicate the oxygen content
 - Sulfate (SO_4^{-2})
 - Sulfite (SO_3^{-2})
 - What is the same?
 - What is different?

Think of it like this...
ATE "ate" ITE, that is why it has more Oxygens

Polyatomic Ions

- Ok, so lets find some more examples of this...
 - What do you notice
 - Does “ate” always mean the same number of oxygens?

Is “Xate” has 3 oxygens, “Xite” will have...

1. Same number of oxygens
2. 1 More oxygens
3. 1 Less oxygens
4. A different charge
5. More than one of the above
6. Trick Question, none of the above

Chlorate and Chlorite have the same charge

1. True
2. False

Assignment

- Page 190 EOSQ (1,3,5,7,8)
- 6.2 Worksheet
- TON 6.3

Compound Names and Formulas

6.3

Key Ideas

- How are ionic compounds named?
- What do the numerical prefixes used in naming covalent compounds tell you?
- What does a compound's empirical formula indicate?

Intro

- Compound names are just 2 element names put together
 - Sodium Chloride
 - Carbon dioxide
 - Iron (II) Oxide
- Similar to words like carport, rearview, etc.

Quick Activity

- Get into groups of 2 and create as many compd words in the next 3 minutes by combining 2 of the words on the next side.
- Ready..... GO

Quick Activity

Binary Ionic Compounds

- The first formulas of compounds you will write are for binary ionic compounds.
- A binary compound is one that is composed of two elements.
 - For example, Sodium Chloride, Potassium Oxide
- Before you can write a formula, you must have all the needed information at your fingertips.
- These compounds will be a combination of a metal and a nonmetal.

Binary Ionic Compounds

- An oxidation number tells you how many electrons an atom has gained, or shared to become stable.
- For ionic compounds the oxidation number is the same as the charge on the ion.
- For example, a sodium ion has a charge of 1+ and an oxidation number of 1+.

Binary Ionic Compounds

- Remember the shortcut
- Group 1, Group 2, Group **13**, ...



Oxidation Number

- The elements in this table can have more than one oxidation number.
- When naming these compounds, the oxidation number is expressed in the name with a roman numeral. For example, the oxidation number of iron in iron (III) oxide is +3.
- Where are these elements located?

Compounds are Neutral

- When writing formulas it is important to remember that although the individual ions in a compound carry charges, the compound itself is neutral.
- A formula must have the right number of positive ions and the right number of negative ions so the charges balance.

Compounds are Neutral

- What if you have a compound like calcium fluoride?
- A calcium ion has a charge of 2+ and a fluoride ion has a charge of 1 -.
- In this case you need to have two fluoride ions for every calcium ion in order for the charges to cancel and the compound to be neutral with the formula CaF_2 .

Charge of Al is...

1. numeric

Charge of Iron (IV) is...

1. Numeric

Fe^{+2} is written as

- A. Iron
- B. Iron (I)
- C. Iron (II)
- D. Iron (III)
- E. Iron (IV)
- F. None of the above
- G. More than one of the above

Overall charge on a compound is
always "0".

1. True
2. False

Ca^{+2} is written as

- A. Calcium
- B. Calcium (I)
- C. Calcium (II)
- D. Calcium (III)
- E. Calcium (IV)
- F. None of the above
- G. More than one of the
above

Writing Formulas

- You can write formulas for ionic compounds
by using the following rules in this order.

1. Write the symbol of the element or
polyatomic ion (ions containing more than
one atom) that has the positive oxidation
number or charge.

Writing Formulas

2. Write the symbol of the element or polyatomic ion with the negative oxidation number.

3. Cross and Drop
- Reduce if possible

Writing Formulas- Practice

- Examples on Board
- Lithium oxide
- Magnesium chloride
- Calcium nitride
- Copper (II) Bromide
- Nickel (III) Oxide
- Magnesium Oxide

Iron (IV) chloride is written as

- A. Fe_4Cl
- B. FeCl_4
- C. Fe_2Cl_4
- D. FeCl_2
- E. Fe(IV)Cl_4
- F. Fe (IV)Cl_2
- G. None of the above

Calcium Oxide is written as

- A. CaO
- B. Ca₂O₂
- C. Ca₂O
- D. CaO₂
- E. CaO₃
- F. None of the above

What is the formula for calcium phosphide?

- A. CaP
- B. Ca₂P₃
- C. Ca₃P₂
- D. Ca₂P₂
- E. None of the above

Writing Names

- You can name a binary ionic compound from its formula by using these rules.

1. Write the name of the positive ion.
2. Check to see if it has more than one oxidation number

Writing Names

3. Write the name of the negative ion.

4. Change the ending to the ***-ide***.

Writing Names

- Subscripts do not become part of the name for ionic compounds.
- However, subscripts can be used to help determine the charges of these metals that have more than one positive charge

Writing Names - Practice

Examples on Board

- MgCl_2
- NaCl

In Your Notebook

- BeO
- K_2S
- AlP

Writing Names - More Practice

- Reverse Cross and Drop for Positive Ions with more than 1 oxidation number (transition metals)

Copy this

- CuO

| Element | Charge | # | Total |
|---------|--------|---|-------|
| Cu | +2 | 1 | +2 |
| O | -2 | 1 | -2 |

More Practice

- FeCl
- CuP
- Fe₂O
- Cu₂O₃

Hg₂O is

- Mercury (II) Oxide
- Mercury Oxide
- Mercury (I) Oxide
- Mercury oxide (II)
- None of the above

CaCl_2 is

- A. Calcium (I) Chloride
- B. Calcium Chloride
- C. Calcium (II) Chloride
- D. Calcium (II) Chloride (I)
- E. None of the above

AgO_2 is

- A. Silver Oxide
- B. Silver(II) Oxide
- C. Silver(IV) Oxide
- D. Silver Oxide (II)
- E. Silver Oxide (IV)
- F. None of the above

Assignment

- 6.3 wkst (1)
 - Work on this in class

Compounds with Complex Ions

- Not all compounds are binary.
- Baking soda has the formula NaHCO_3 .
- This is an example of an ionic compound that is not binary.

Compounds with Complex Ions

- Some compounds, including baking soda, are composed of more than two elements. They contain polyatomic ions.

Compounds with Complex Ions

- A **polyatomic ion** is a positively or negatively charged, covalently bonded group of atoms.
- So the polyatomic ions as a whole contains two or more elements.

Writing formulas

On Board

- Ammonium oxide
- Calcium Hydroxide

In Notebook

- Sodium Phosphate
- Magnesium Sulfate
- Iron (III) Sulfate
- Copper (I) Carbonate

Lead (I) Phosphate

- A. Pb_3P
- B. Pb_3PO_3
- C. Pb_3PO_4
- D. None of the above

Copper (IV) sulfite

- A. CuS_2
- B. Cu_2S_4
- C. $\text{Cu}(\text{SO}_4)_2$
- D. $\text{Cu}_2\text{SO}_{44}$
- E. $\text{Cu}_2(\text{SO}_4)_4$
- F. More than one of the above
- G. None of the above

Writing Names

- The table lists several polyatomic ions.
- To name a compound that contains one of these ions, first write the name of the positive ion.
- Then write the name of the negative ion.

Writing Names

- To write formulas for these compounds, follow the rules for binary compounds, with one addition.
- When more than one polyatomic ion is needed, write parentheses around the polyatomic ion before adding the subscript.
- If there is MORE than 2 elements in the chemical formula, a polyatomic ion IS present!

Writing Names - Practice

Examples on Board

- CaSO_4
- NaNO_3
- NaOH

In Notebook

- $\text{Ca}(\text{OH})_2$
- Na_2SO_4

Writing Names – More Practice

- AlPO_4
- $\text{Al}(\text{OH})_3$
- LiClO_3
- NH_4Cl
- $(\text{NH}_4)_2\text{O}$
- NH_4OH
- $(\text{NH}_4)_2\text{CO}_3$

The name for LiClO_3 is

- A. Lithium Chloride
- B. Lithium (I) Chloride
- C. Lithium Chlorate
- D. Lithium (I) Chlorate
- E. None of the above

The name for $\text{Al}_2(\text{OH})_3$ is

- A. Aluminum Hydroxide
- B. Aluminum (II) Hydroxide
- C. Aluminum (II) Hydroxide (III)
- D. Aluminum (III) Hydroxide (II)
- E. None of the above

The name for Na_2O is

- A. Sodium (II) Oxide
- B. Sodium oxide
- C. Sodium (I) oxide
- D. Sodium oxide (II)
- E. None of the above

The chemical formula for Potassium
hydroxide is

- A. KOH
- B. KOH_2
- C. $\text{K}(\text{OH})_2$
- D. $\text{K}_2(\text{OH})$
- E. $\text{K}_2(\text{OH})_2$
- F. None of the above

The chemical formula for potassium
carbonate is

- A. KCO_3
- B. $\text{K}(\text{CO}_3)$
- C. $\text{K}(\text{CO}_3)_2$
- D. K_2CO_3
- E. $\text{K}_2(\text{CO}_3)$
- F. $\text{K}_2(\text{CO}_3)_2$
- G. None of the above

The chemical equation for aluminum hydroxide is

- A. AlOH
- B. AlOH_2
- C. AlOH_3
- D. AlOH
- E. $\text{Al}(\text{OH})_2$
- F. $\text{Al}(\text{OH})_3$
- G. $\text{Al}_2(\text{OH})_2$
- H. $\text{Al}_2(\text{OH})_3$

Writing Chemical Formulas

- Covalent formula are written differently than ionic
- **Look to see if a metal and a non-metal is bonded (ionic) or if 2 or more nonmetals are bonded (covalent)
- If it is ionic, follow the steps we have already learned

Writing Covalent Formulas

- If 2 nonmetals are bonded then...
- The first element is always named first using the entire element name.
 - Ex. Nitrogen, Carbon...
- The second element is named using its root and adding the suffix *-ide*.
 - Ex. sulfide, bromide

Writing Covalent Formulas

- Prefixes are used to indicate the number of atoms of each element in a compound.

Naming Binary Covalent Compounds

- Covalent compounds are those formed between elements that are nonmetals.
- Some pairs of **nonmetals** can form more than one compound with each other.
- In the system you have learned so far, each of these compounds would be called nitrogen oxide. You would not know from that name what the composition of the compound is.

Writing Formulas

- Examples on Board
- Carbon monofluoride
- Carbon trifluoride
- Disulfur tetroxide
- Trinitrogen dibromide

Writing Names

- Examples on Board

- CO
- CO₂
- N₂O

What is the chemical formula for carbon monoxide?

- A. CO
- B. CO₂
- C. C₂O₂
- D. None of the above

What is the chemical formula for dinitrogen pentoxide?

- A. NO
- B. N₂O
- C. N₂O₅
- D. N₅O₂
- E. None of the above

What is the name for NF?

- A. Nitrogen fluoride
- B. Dinitrogen fluoride
- C. Nitrogen difluoride
- D. None of the above

What is the name for S₃O₄?

- A. Silicon tetroxide
- B. Disilicon tetroxide
- C. Trisilicon tetroxide
- D. None of the above

Empirical Formulas

- *What does a compounds empirical formula indicate?*
- The **empirical formula** tells you the smallest whole-numbered ratio of elements in a compound
- The **molecular formula** tells you the ACTUAL number of elements in a compound



How to find the Chemical Formula

- One mole of an unknown compound contains 62 g of phosphorus and 80 g of oxygen. What is the empirical formula of this compound?
1. Write the atomic masses (from the PT)
phosphorus: 30.97 g/mol
oxygen: 16.00 g/mol

How to find the Chemical Formula

- 2. Find the molar ratio

$$\frac{62 \text{ g P}}{30.97 \text{ g P}} \left| \frac{1 \text{ mole P}}{30.97 \text{ g P}} \right. = 2 \text{ mole P}$$

$$\frac{80 \text{ g O}}{16.00 \text{ g O}} \left| \frac{1 \text{ mole O}}{16.00 \text{ g O}} \right. = 5 \text{ mole O}$$

Answer:

Practice

- Find the chemical formula for the following and also state if it is a molecular or empirical formula.
- If it is the molecular formula, what is the empirical formula?
 - a. 2.01 grams of H and 16 grams of O
 - b. 2.01 grams of H and 32 grams of O
 - c. 28.02 g N, 96.21 g S
 - d. 72.06 g C, 12.12 g H, 96 g O

Assignment

- 6.3 wkst (3)

Organic and Biochemical Cmpds

6.4

Key Ideas

- What is an organic cmpd?
- What is a polymer?
- What organic cmpds are essential to life?

Organic Cmpds

- *What is an organic cmpd?*
- An organic cmpd is a covalently bonded cmpd that contains carbon.
- **Organic cmpd:** a covalently bonded cmpd that contains carbon, excluding carbonates and oxides

Organic Cmpds

- Carbon atoms can form up to 4 covalent bonds in organic cmpds
- A Hydrocarbon is a cmpd made only of C and H atoms (makes sense)
- Alkanes are hydrocarbons that only have single bonds



Alkane Properties

1. Nonpolar
2. Lowest molecular mass alkanes are gases
3. High molecular massed alkanes are solids
4. Boiling points increase with increasing molecular mass
5. They are not very reactive



Organic Cmpds

- Arrangements of C atoms in alkanes may vary
 - The carbon atoms in any alkane with more than three carbon atoms can have more than one possible arrangement.
 - Carbon atom chains may have many branches, and they can even form rings.
- Alkane chemical formulas usually follow a pattern
 - The number of hydrogen atoms is always two more than twice the number of carbon atoms, except for cyclic alkenes.



Does this equation work?

- C_nH_{2n+2} Some examples

Look at Page 199 – Figure 3

Organic Cmpds

- *Alkenes* are hydrocarbons that have double carbon-carbon bonds.
 - The simplest alkene is ethene Chem Formula $H_2C=CH_2$
- *Alcohols* have *hydroxyl*, or $-OH$, groups.
 - Example: methanol, CH_3OH
 - Alcohols have the suffix *-ol* in their names.
- Alcohol and water molecules behave similarly.
 - Neighboring alcohol molecules are attracted to one another.



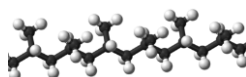
Polymers

- *What is a Polymer?*
- A **polymer** is a molecule that is a long chain made of smaller molecules
- A **monomer** is the smaller molecule that makes up the polymer



Polymers

- Some polymers are natural, and others are artificial.
 - natural polymers: rubber, starch, protein, and DNA
 - human-made polymers: plastics and synthetic fibers
- A polymer's structure determines its elasticity.
 - Polyethylene is made of long chains.
 - It is flexible, but not elastic.
 - milk jugs
 - Polymers with connected chains are elastic.
 - They can stretch.
 - rubber bands



Biochemical Cmpds

- *What organic cmpds are essential to life?*
- The biochemicals essential to life, include
 - Carbohydrates
 - Proteins
 - DNA
