Introduction

Inorganic chemistry is a subdiscipline of chemistry involving the scientific study of the properties and chemical reactions of all chemical elements and chemical compounds other than the vast number of organic compounds (compounds containing at least one carbon-hydrogen covalent bond).\(^\text{[1],[2]}\)

There are a number of subdivisions of inorganic chemistry such as the five subdivisions of the American Chemical Society's Division of Inorganic Chemistry (ASC DIC), namely organometallic chemistry, bioinorganic chemistry, solid-state and materials chemistry, coordination chemistry and nanoscience.\(^\text{[3]}\)

Inorganic chemistry is closely related to other disciplines such as materials science, earth science, mineralogy, geology and crystallography.

Distinctions between inorganic and organic chemistry

The distinction or boundary between inorganic chemistry and organic chemistry is not very well defined. In general, the above definition of inorganic chemistry seemingly excludes carbon compounds but it does not exclude elemental carbon itself. Hence, carbon oxides, carbon sulfides, cyanides and cyanates, metallic carbides and carbonates are included as inorganic compounds.\(^\text{[4]}\)

As another example of the ill-defined distinction between inorganic and organic chemistry, oxalic acid (H\(_2\)C\(_2\)O\(_4\)) is commonly considered to be an organic compound even though it does not contain a carbon-hydrogen bond.

Classification of inorganic compounds

Inorganic chemistry encompasses a very complicated variety of substances which the distinguished American chemist, F. Albert Cotton (1930 – 2007), grouped into these four classes:\(^\text{[5]}\)

**The chemical elements:** These have a variety of structure and properties and include:

- Atomic gases such as argon (Ar) and krypton (Kr), as well as molecular gases such as hydrogen (H\(_2\)) and oxygen (O\(_2\)).
- Molecular solids such as the phosphorus allotrope (P\(_4\)), the sulfur allotrope (S\(_8\)), and the carbon allotrope (C\(_{60}\)).\(^\text{[6]}\)
- Network solids such as diamonds and graphite.\(^\text{[7]}\)
- Metals, either solid such as copper (Cu) and tungsten (W) or liquid such as mercury (Hg) and gallium (Ga).

**Ionic compounds:** These are always solids at \(0 \, ^\circ\text{C}\) temperature and 101.325 kPa absolute pressure and include:

- Simple ionic compounds such as sodium chloride (NaCl), which are soluble in water or other polar solvents.
- Ionic oxides that are insoluble in water, such as zirconium oxide (ZrO\(_2\)) and mixed oxides such as the mineral "spinel" (MgAl\(_2\)O\(_4\)), the mineral "diopside" (CaMg(SiO\(_3\))\(_2\)) and various silicates.
This is a reaction in which two compounds exchange bonds or ions to form two new compounds. Examples include:

Metathesis reaction: (also referred to as exchange or double displacement or double replacement reaction)

\[ \text{Ca}^2+ \text{CO}_3^2- + \text{Cu}^2+ \text{SO}_4^{2-} \rightarrow \text{Cu}^2+ \text{CO}_3^2- + \text{Ca}^2+ \text{SO}_4^{2-} \]

This is a reaction characterized by one element being displaced from a compound by another element. Examples include:

\[ \text{Zn} + \text{CuSO}_4 \rightarrow \text{Cu} + \text{ZnSO}_4 \]

This is a reaction in which a chemical compound is separated into elements or simpler compounds. It is often defined as being a thermal or electrolytic or catalytic decomposition reaction.

\[ \text{CaCO}_3 + \text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2 \]

These may be solids, liquids or gases and include:

- Gases: Hydrogen, oxygen, sulfur dioxide (SO\(_2\)), and osmium tetroxide (OsO\(_4\)).
- Liquids: Water, peroxide (H\(_2\)O\(_2\)), and the ferricyanide anion ([Fe(CN)\(_6\)]\(^3-\)).
- Solids: Sodium chloride (NaCl), silicon hexafluoride anion ([SiF\(_6\)]\(^2-\)), and the cobalt hexammine cation ([Co(NH\(_3\))\(_6\)]\(^3+\)).

Typical inorganic chemical reactions

Typical inorganic chemical reactions are those that involve various inorganic compounds and inorganic structures. These include various inorganic compounds and inorganic structures. Some examples of these reactions are:

1. **Decomposition Reaction**: (also referred to as thermal, electrolytic or catalytic decomposition reaction)

\[ \text{H}_2\text{O} \rightarrow \text{H}_2 + \text{O}_2 \]

2. **Combustion Reaction**: These may be solids, liquids or gases and include:

\[ \text{C} + \text{O}_2 \rightarrow \text{CO}_2 \]

3. **Reduction Reaction**: These include various inorganic compounds and inorganic structures. Some examples of these reactions are:

\[ \text{Fe} + \text{O}_2 \rightarrow \text{Fe}_2\text{O}_3 \]

Other binary halides, nitrides, oxides, sulfides, and similar materials, a few compounds are listed above (AgCl, silicon carbide (SiC), zirconium (Zr(CH\(_3\))\(_4\)), and phosphorus trifluoride (PF\(_3\)).

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Precipitation reaction: (a specific type of metathesis referred to as *aqueous metathesis*)

This is a reaction that occurs when two inorganic salt solutions, as in the example below, react to form a solution containing a soluble product and another product that is insoluble and precipitates out of the solution:

- calcium chloride + silver nitrate ⇒ calcium nitrate + silver chloride  
  (Insoluble silver chloride precipitates out of the aqueous solution.)

\[ \text{CaCl}_2 (aq) + 2\text{AgNO}_3 (aq) \rightarrow \text{Ca(NO}_3)_2 (aq) + 2\text{AgCl (s)} \]

Neutralization reaction: (another specific type of metathesis that is sometimes referred to as an *acid-base* reaction)

This is a reaction in which an acid and a base react to form a salt. Water is also produced in neutralizations with Arrhenius acids,[13] that dissociate in aqueous solution to form hydrogen ions (H\(^+\)), and Arrhenius bases, that form hydroxide ions (OH\(^-\)). However, water is not produced in all neutralizations as can be seen below in the neutralization of ammonia. Examples include:

- nitric acid + sodium hydroxide ⇒ sodium nitrate + water
  \[ \text{HNO}_3 + \text{NaOH} \rightarrow \text{NaNO}_3 + \text{H}_2\text{O} \]
- hydrochloric acid + ammonia ⇒ ammonium chloride
  \[ \text{HCl} + \text{NH}_3 \Rightarrow \text{NH}_4\text{Cl} \]

Redox reaction: (also referred to as *oxidation-reduction* reaction)

This is a reaction in which the oxidation numbers of atoms are changed. Examples include:

- hydrogen + fluorine ⇒ hydrogen fluoride
  \[ \text{H}_2 + \text{F}_2 \Rightarrow 2\text{HF} \]
  Hydrogen is oxidized by its oxidation number increasing from zero to +1. Fluorine is reduced by its oxidation number decreasing from zero to -1.
- iron + cupric sulfate ⇒ ferrous sulfate + copper
  \[ \text{Fe} + \text{CuSO}_4 \Rightarrow \text{FeSO}_4 + \text{Cu} \]
  Iron is oxidized by its oxidation number increasing from zero to +2. Copper is reduced by its oxidation number decreasing from +2 to zero.

Analysis and characterization of inorganic compounds

The number of known chemical elements that occur naturally on Earth is 94 and the number of diverse inorganic chemical compounds derived by combinations of those elements is virtually innumerable. The characterization of those compounds includes the measurement of chemical and physical properties such as boiling points, melting points, density, solubility, refractive index and the electrical conductivity of solutions.

The techniques of qualitative and quantitative analytical chemistry can provide the composition of a chemical compound in terms of its constituent chemical elements and can thus determine the chemical formula of a compound.

Modern laboratory equipment and techniques can provide many more details for characterizing chemical compounds. Some of the more commonly used modern techniques are:

- Chromatography: A process for separating mixtures of chemicals into their component constituents.
- X-ray diffraction or X-ray crystallography: A technique that determines the three-dimensional arrangement of atoms within a molecule.
- Spectrometry or qualitative Spectroscopy: A technique for the identification of substances through the electromagnetic spectrum emitted from or absorbed by them.
- Voltammetry: An electrochemical method for studying a chemical substance by measuring the electrical potential and/or electric current in an electrochemical cell containing the substance.

References

1. *Inorganic Chemistry: A Study Guide*, From the website of the University of Waterloo, Canada

3. Welcome to the ACS DIC Webpage!, From the website of the American Chemical Society Division of Inorganic Chemistry.

4. Note: For example, carbon monoxide (CO), carbon dioxide (CO$_2$), carbon disulfide (CS$_2$), sodium cyanide (NaCN), potassium cyanate (KOCN), silicon carbide (SiC) and calcium carbonate (CaCO$_3$)


6. Note: Allotropes are molecules having different molecular structures. This differs from isotopes which are elements having different atomic structures (i.e., the same number of protons but different numbers of neutrons in the atomic nucleus). The carbon allotrope (C$_{60}$) is also known as Buckminsterfullerine.

7. Note: Network solids are chemical compounds with the atoms being bonded by covalent bonds in a continuous network. Thus, there are no individual molecules in a network solid and the entire solid may be considered to be a macromolecule. Diamond is an example of a network solid with a continuous network of carbon atoms. Another example is graphite, which consists of continuous two dimensional layers of carbon atoms covalently bonded within each layer and with other bond types holding the layers together.

8. Yttrium Barium Copper Oxide – YBCO, From the wiki of the Chemistry Department at Imperial College, London, England.


10. Types of Equations, From the website of the Virginia Polytechnic Institute and State University.

11. Types of Inorganic Chemical Reactions: Four General Categories, Dr. Anne Marie Helmenstine on the website of About.com: Chemistry.

12. Types of Chemical Reactions: List of Common Reactions and Examples, Dr. Anne Marie Helmenstine on the website of About.com: Chemistry.

13. Note: An Arrhenius acid is defined as dissociating in aqueous solution to form hydrogen ions and Arrhenius bases, which form hydroxide ions. There are a number of other theories and definitions of acids, namely Brønsted-Lowry acid-base theory, Lewis acids and bases,Usanovitch definition, and various others.

Source:
http://www.eoearth.org/view/article/51cbf2757896bb431f6a96fc/?topic=51cbfc98f702fc2ba812ea6