Arsenic is situated in the 33rd spot on the periodic table, right next to Germanium and Selenium. Arsenic has been known for a very long time and the person who may have first isolated it is not known but credit generally is given to Albertus Magnus in about the year 1250. The element, which is classified as a metalloid, is named from the Latin arsenicum and Greek arsenikon which are both names for a pigment, yellow orpiment.

Arsenic played a major role in the Bronze Age, as it was added to bronze as a strengthener.

<table>
<thead>
<tr>
<th>Atomic number</th>
<th>33</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic symbol</td>
<td>As</td>
</tr>
<tr>
<td>Atomic weight</td>
<td>74.92</td>
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<tr>
<td>Classification</td>
<td>Metalloids</td>
</tr>
<tr>
<td>Electron Configuration</td>
<td>[Ar]4s²3d¹⁰4p³</td>
</tr>
<tr>
<td>Phase</td>
<td>Solid</td>
</tr>
<tr>
<td>Density</td>
<td>5.727 g/cm³</td>
</tr>
<tr>
<td>Oxidation States</td>
<td>5,3,2,1,-3</td>
</tr>
<tr>
<td>Crystal Structure</td>
<td>rhombohedral</td>
</tr>
</tbody>
</table>

**Natural Sources**

Arsenic is found in the earth’s crust, most commonly in the form of \((FeAsS)\), or Iron Arsenide Sulfide. Arsenic can also be found in the atmosphere as arsenic trioxide dusts, a by-product of industrial smelting operations. Arsenic is usually very toxic, especially in the cases of inorganic arsenic compounds such as arsenic trichloride and arsenous acid. Arsenic compounds have also found their way into rivers and wells, contaminating the drinking water of millions of people. Due to numerous reactions that can occur with Arsenic, this element can be encountered in various phases.

**Reactions**

**Reaction of Arsenic with hydrogen:** Arsenic trioxide can be reduced by hydrogen gas to form arsine. Arsine, \((AsH_3)\), is a very toxic gas that is denser than air. When arsine is heated, it breaks down to arsenic and hydrogen.

- Reaction of arsenic trioxide with hydrogen gas to form water and arsine:

  \[
  AS_2 O_3(s) + 6H_2(g) \rightarrow 3H_2O(l) + 2 AsH_3(g)
  \]

**Reaction of Arsenic with oxygen:** Solid arsenic is oxidized when exposed to oxygen. The surface of the metalloid
becomes black. When heated in oxygen gas, arsenic binds with oxygen to form tetraarsenic decaoxide, or arsenious oxide.

- Reaction of arsenic with oxygen gas to form arsenuous oxide:
  \[4 \text{As}_\text{(s)} + 5 \text{O}_\text{(g)} \rightarrow \text{As}_4\text{O}_{10(\text{s})}\]  

**Reaction of Arsenic with halogens**: Arsenic reacts well with halogens with the exception of astatine. Arsenic pentafluoride is a highly toxic colorless gas. When liquid arsenic trichloride is cooled with free chlorine molecule, arsenic pentachloride can be formed. Solid arsenic with bromine gas forms a light yellow solid called arsenic tribromide.

- Reaction of arsenuous oxide with hydrochloric acid to form water and arsenic trichloride:
  \[\text{As}_4\text{O}_6 + 12 \text{HCl}_\text{(aq)} \rightarrow 4 \text{AsCl}_3\text{(l)} + 6\text{H}_2\text{O}_\text{(l)}\]  
- Reaction of arsenic trichloride with Cl\(_2\) to form arsenic pentachloride:
  \[\text{AsCl}_3\text{(l)} + \text{Cl}_2\text{(g)} \rightarrow \text{AsCl}_5\text{(s)}\]  
- Reaction of solid arsenic with bromine gas:
  \[2 \text{As(s)} + \text{I}_2\text{(g)} \rightarrow 2\text{AsI}_3\text{(s)}\]

**Reaction of Arsenic with water**: Pure arsenic is insoluble in water; however, many arsenic compounds dissolve easily in water. Arsenic in the form of arsenic trisulfide, and arsenic acid are examples of arsenic compounds that have found their ways into water supplies.

- Reaction of arsenic trisulfide with water to form hydrogen sulfide and arsenuous acid:
  \[\text{As}_2\text{S}_3\text{(s)} + 6\text{H}_2\text{O}_\text{(l)} \rightarrow 3\text{H}_2\text{S}_\text{(g)} + 2\text{H}_3\text{AsO}_3\text{(aq)}\]

**Figure 1**: Sample of solid Arsenic. Image used with permission from Wikipedia.

### Isotopes of Arsenic

The atomic mass of Arsenic listed on the periodic table is 74.92 u. Arsenic has over 33 different isotopes, ranging
from 60 to 92 in atomic mass. However, only one of these isotopes is stable, which is $^{75}$As. Therefore, Arsenic is a monoisotopic element. Like the rest of the nitrogen group, Arsenic has five valence electrons. In group five, Arsenic is most closely related to antimony, both being metalloids. Since nitrogen and phosphorus are non-metal, they share very little commonalities with arsenic and antimony. As with bismuth being a P-block metal, they too share very little similarities.

Old Usage

Some arsenic compounds are used in the manufacture of everything from wallpaper to ceramics. Arsenic in the 1800s was commonly used in the form of copper arsenite, a green compound that was used as a pigment to color wallpaper and paint. This caused a lot of health problems. As mold and bacteria fed on the wallpaper and paint, they released trimethylarsine, C$_3$H$_9$As, which became airborne and inhaled. This would lead to arsenic poisoning and in some cases, death. It was substituted by copper carbonate by the end of the 1800s as the primary green pigment.

Of course, arsenic is most often thought of in terms of its toxicity and it is used as a weed killer and rat poison. Intentional arsenic poisoning is now pretty much the stuff of old murder mysteries. Originally arsenious oxide was administered in small doses over a period of time, precipitating death accompanied by symptoms reminiscent of pneumonia. Today the arsenic remaining in the body can be detected during autopsy so this is not (happily) a very effective way to dispatch people undetected.

Since Arsenic is toxic to most organisms, it is praised as an herbicide, and pesticide. For example, copper arsenate, Cu$_3$(AsO$_4$)$_2$, mixed with chromium is a pesticide used to treat wood. As of 2004, CCA, chromium copper arsenate, has been put into restricted use by the EPA. In the 1900s copper acetarsenate, or Paris Green, was used as an insecticide and fungicide in many agricultural farmland. Agent blue is one of the herbicides used during the Vietnam War by the US to destroy Vietnam rice farm. It is a blend of cacodylic acid, (CH$_3$)$_2$AsO$_2$H, and sodium cacodylic, an arsenic salt.

Modern Usage

Tiny amounts of arsenic are used today in the semiconductor industry to create light emitting diodes (LEDs). Since arsenic is a semi-metal, arsenic in the form of gallium arsenide is now used as a semiconductor for transistors and other electronic devices. It is used to make LED, light emitting diodes, and in some cases, it can substitute silicon in integrated circuits.

Problems

1. What is Gallium Arsenide now used for in the electronic industry?
2. Complete and balance: $2\text{As} + 5\text{F}_2 \rightarrow ?$
3. True or false: Arsenic is more like antimony than phosphorus.
4. True or False: Arsenic trioxide is a gas.
5. Complete and balance: $\text{As(s)} + \text{H}_2\text{O(l)} \rightarrow ?$
Solutions

Highlight to see: (Easy-Medium-Hard)

1. Gallium arsenide is now used for transistors. (H)
2. $2\text{As}+5\text{F}_2\rightarrow2\text{AsF}_5$ (E)
3. True, both arsenic and antimony are semi-metals. (M)
4. False, arsenic trioxide is a solid. It can, however, be disperse in the air as dust. (M)
5. No reaction. Solid arsenic does not react well with water. (M)

References


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