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|  | Insulators | Semiconductors | Conductors |
| Periodic Table | Non-Metals | Metalloids | Metal |
| Elements | * Sulfur * Iodine | * Silicon * Germanium | * Silver * Gold * Copper * Steel * Zinc * Aluminum |
| Conductivity and Temperature | Direct Relationship  ↑ T = ↑ C (↓ R) | Direct Relationship  ↑ T = ↑ C (↓ R) | Inverse Relationship  ↑ T = ↓ C (↑ R) |
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|  | N-type | P-type |
| Charge Carriers | Electrons (-) – movement of free unbonded electrons | Holes – movement of holes or vacancies |
| Examples | Si + P  Si has 4 valance electrons, P has 5.  ONLY 4 valance electrons are used in binding. 5th valance electron of P is free. | Al + Si  Si has 4 valance electrons vs Al which only has 3. A hole will be created because 1 of Si’s valance electrons cannot connect with any other valance electrons. Al now has a hole. |
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**PN Junctions:**

* PN Junction = N-type + P-type
* The free valance electrons in N-type semiconductors fill in the holes in the P-type semiconductors
* IF N-type to P-type; THEN semiconductor N-type is going to lose an electron and thus make the atom positive, the P-type is going to be negative because of the buildup of negative charges from the traveling valance electrons (N to P)

**Formal Charge**:

* Formal Charge = Normal Valance Electrons to be stable - (Bonds + Free valance electrons)
* IF the normal amount of valance electrons is present in the atom, then the charge is neutral
* IF the atom has less than the normal amount of valance electrons (EX N side of PN Junctions) THEN it is positively charged because it is missing a valance electron which is negatively changed. THUS, the formal charge is positive.
* IF the atom has more than the normal amount of valance electrons (EX P side of PN Junction) the holes in the P-type are getting filled up to valance electrons. THEN the atom is negatively changed because it is receiving negatively charged valance electrons which are above the normal number of electrons in an atom.
* In the end, when the force that pulls free valance electrons is created by the holes on the other side of the PN junction which is on the P side, is in equilibrium with the force of the negatively charged electrons on the P side which repel the electrons on the N side. It creates a constant **junction potential**