Physical Science Study Guide
Unit 2
Sub-Atomic Particles, Periodic Table and Radiation (Nuclear Fission & Fusion)

Sources: **CP**, Chapters 10 and 18 (parts of 20) **Honors**, Chapters 2 and 7

Indicators:

PS-2.1 **Compare** the subatomic particles (protons, neutrons, electrons) of an atom with regard to mass, location, and charge, and explain how these particles affect the properties of an atom (including identity, mass, volume, and reactivity)

PS-2.2 **Illustrate** the fact that the atoms of elements exist as stable or unstable isotopes

PS-2.3 **Explain** the trends of the periodic table based on the elements' valence electrons and atomic numbers

PS-2.4 **Use** the atomic number and the mass number to calculate the number of protons, neutrons, and/or electrons for a given isotope of an element

PS-2.5 **Predict** the charge that a representative element will acquire according to the arrangement of electrons in its outer energy level

PS-2.6 **Compare** fission and fusion (including the basic processes and the fact that both fission and fusion convert a fraction of the mass of interacting particles into energy and release a great amount of energy)

PS-2.7 **Explain** the consequences that the use of nuclear applications (including medical technologies, nuclear power plants, and nuclear weapons) can have

Key Terms and Concepts:

Halogens	Noble Gases	Alkali Metals
Alkaline earth Metals	Transition Metals	Family/group
Valence Electrons	Period	Octet rule
Metals	Nonmetals	Metalloids
Stair-step line	Chemical stability	Lewis dot structures
Oxidation Number	Ion	Chemical Formula
Group/Family	Period	Valence electrons
Isotopes	Periodic Table	Subatomic Particles
Atomic Number	Mass Number	(Average) Atomic Mass
Fusion	Fission	

Subatomic Particles:

An atom is composed of ***subatomic particles*** (***protons***, ***neutrons***, and ***electrons***) that ***affect*** the ***properties*** of an atom.
Protons and ***neutrons*** have about the ***same mass***.
The ***mass*** of an ***electron*** is much ***less*** than the mass of protons and neutrons.
Protons have a ***positive*** charge; ***neutrons*** have ***no*** charge, ***electrons*** have a ***negative*** charge.
The ***net charge*** of the ***nucleus*** is ***positive*** and ***equal*** to the ***number of protons***.
There is an ***attractive*** force between negative electrons and positive protons (***unlike charges attract***).
There is a ***repulsive*** force between electrons and electrons, and between protons and protons (***like charges repel***).
Atoms are ***neutrally*** charged when the number of electrons is the same as the number of protons.
Protons and neutrons are tightly bound in a ***tiny nucleus***.

The ***total region in space*** where electrons are likely to be found around the nucleus of an atom is often called the '***electron cloud'***. The volume of the 'electron cloud' determines the volume of the atom. The nucleus of an atom as a tiny speck in the center of an atom and the electron cloud as an area outside the nucleus where electrons are moving erratically like bees around a beehive, hence, the volume of space occupied by the electrons is much greater.
As the ***energy levels*** of electrons increase, the regions of space where the electrons are likely to be found are at increasing distances from the nucleus.
There are a maximum number of electrons that can occupy each energy level and that number increases the further the energy level is from the nucleus.
The number of protons determines the identity of an atom (i.e. an element).
Atoms of the same element have the same number of protons. The number of neutrons may vary (i.e. isotopes).
An atom of a given element may lose or gain electrons yet it still remains the same element.
The total number of protons and neutrons within its nucleus is a major determinant for the mass of the atom, because the mass of the atom's electrons is insignificant by comparison.
Particles in the nucleus of the atom do ***not*** change in a chemical reaction.
Chemical reactions occur because the electrons around the atoms are ***exchanged*** or ***shared***. The number of electrons in the outer energy level of the atom and the relative distance from the nucleus of these outer-energy level electrons determine how the atom will react chemically.
The electrons with more energy can move further from the nucleus, those with less energy stay closer. The space where the electrons are moving makes up the vast majority of the volume of the atom.
Atomic number of an element is equal to the number of protons. The atomic number is always the same for a given element. The atomic number of an element can be found on the periodic table. It is a whole number since it is equal to the number of protons in the nucleus of the atom and is, therefore, the same for all atoms of that element.
Mass number of an atom **=** ***number of protons + number of neutrons***.
Atoms of the same element with different numbers of neutrons will have different mass numbers.
Isotopes are defined as two or more atoms of the same element having the same number of protons but ***different*** numbers of ***neutrons*** (and therefore ***different masses***)
Atomic mass of an element is the ***weighted average*** of the masses of the naturally occurring isotopes of an element. The atomic mass of an element can be found on the periodic table. Since the atomic mass of an element is an average, it is usually not a whole number.
In order for a nucleus to be stable, a correct ratio of neutrons and protons should be present in the nucleus.
An isotope with an unstable nucleus is radioactive.
Due to the unstable condition of the nucleus, radioactive isotopes undergo nuclear decay.
Nuclear decay is a nuclear reaction that involves emission of energy and/or particles from the nucleus, resulting in a more stable nuclear environment.
Radiation - particles and/or energy that are emitted ***during nuclear decay***.
Three types of decay particles are alpha and beta particles, and gamma rays.
Nuclear decay occurs naturally in many elements that are common on earth and there is always some radiation present in every environment.

<u>Periodic Table Trends</u>:
Period - is the term used to describe a ***horizontal row*** on the periodic table.
Group/family - terms used to describe a ***vertical column*** on the periodic table.
Locate the major categories of elements such as the ***metals***, ***metalloids***, and ***nonmetals***.

Metalloids - have some characteristics of metals and some of nonmetals and border the line (***stair-case***) between metals and nonmetals on the periodic table.
Locate referenced elements when prompted with a period number or group number.
Be able to ***determine*** a given element's ***atomic number*** (i.e. # of protons).
Be able to ***determine*** the number of ***electrons*** for an atom of a given element (i.e. is the same as the # of protons, its atomic number).
Be able to ***determine*** how many ***energy levels*** are occupied in a given element by recognizing that the ***period*** in which an element appears on the periodic table indicates the number of occupied energy levels. For example, all elements in ***period 4*** have ***four*** occupied energy levels.
Recognize a given element's ***atomic mass*** (the weighted average of the masses of the naturally occurring isotopes of the element) by recognizing that the atomic mass of an element is a decimal number. It is always ***larger*** than the ***atomic number*** and generally increases for each successive element.
Be able to ***determine*** the number of ***valence electrons*** (electrons in the outer-most energy level) for selected groups of elements when given the element's group number or name.
For example;

Group or Family	**Name**	**# valence electrons**
1	Alkali metals	1
2	Alkaline Earth Metals	2
13		3
14		4
15		5
16	Oxygen group	6
17	Halogens	7
18	Noble Gases	8 (except He)

Know the following Periodic trends;
From left to right across Periodic Table – atoms of elements contain one more valence electron than the atoms of the previous element.
Top to bottom within any group - atoms of all of the elements in a given group contain the same number of valence electrons.
Left to right across any period - atoms of all elements in a given period have the same number of energy levels.
Top to bottom down the Periodic Table – the # of ***energy levels increases***
Top to bottom within any group - atoms of each subsequent element (from top to bottom) in any given group contain one more energy level than the atoms of the element above.
Be able to perform the following calculations:
Given the symbol for an isotope of an element (which includes the element's symbol and the mass number of the isotope), determine the number of protons, neutrons, and electrons.
Determine the number of protons and the number of electrons from the periodic table. Calculate the number of neutrons from the equation.
When given the mass number and the number of neutrons for a particular isotope of an unknown element, write the symbol for the isotope.
Write the symbol for the isotope

$^{27}_{13}Al$ or Al-27 $^{238}_{92}U$ or U-238

Only ***electrons*** are involved in ***chemical reactions*** (# of protons, neutrons remain constant). Atoms tend to lose, gain or share electrons to have the same number of *valence electrons* (electrons in the outer-most energy level) as one of the stable elements, i.e. Noble Gases.

Predict how many ***electrons*** an atom of a given element will ***gain*** or ***lose*** in order to most readily reach chemical stability based on the following generalizations:

Elements in group 18 are stable (2 or 8 electrons in outer energy level) - do not gain or lose electrons except under extreme conditions.

Elements in groups 1 and 2 tend to lose 1 and 2 electrons respectively.

Elements in groups 16 and 17 tend to gain 2 and 1 electron respectively.

Elements in groups 13-15 are less likely than those listed above to either gain or lose electrons because they have 3, 4, and 5 valence electrons respectively.

If a neutral atom loses electrons, the particle formed will have a positive charge and if a neutral atom gains electrons, the particle formed will have a negative charge. The charged particle is called an ***ion***. The ion formed is chemically stable.

Some of the chemical properties of metals and nonmetals are due to their tendency to lose or gain electrons.

Nuclear Energy:

Nuclear reactions involve ***particles*** in the ***nucleus*** of the atom (as opposed to chemical reactions, which involve the electrons in an atom and where the nucleus remains intact).

Nuclear fission - occurs when a heavy nucleus, such as the U-235 (Uranium) nucleus, ***splits*** into two or more parts and a ***large amount of energy*** is released. The absorption of a neutron by a large nucleus (such as U-235) is one way to initiate a fission reaction. When an atom with a large nucleus undergoes fission, atoms that have ***smaller nuclei*** result. In the process smaller particles, such as neutrons, may be ejected from the splitting nucleus and if one or more of these neutrons strike another U-235 nucleus, another fission reaction may occur and the continuation of this process is called a ***chain reaction***. There must be a certain minimum amount of mass, called a ***critical mass***, of fissionable material in close proximity for a chain reaction to occur.

Fission occurs in ***nuclear power plants*** and other nuclear applications (atomic bombs, nuclear-powered submarines and satellites). The mass of the products of a fission reaction is less than the mass of the reactants. The equation $E = mc^2$ shows the relationship of this "***lost mass***" to the ***energy released***. The conversion of mass to energy during a nuclear reaction involves ***far*** more energy than the amount of energy involved in a chemical reaction.

Nuclear fusion - occurs when light nuclei (such as hydrogen) fuse, or combine, to form a larger single nucleus (such as helium). As in fission reactions, in fusion reactions the mass of the products is less than the mass of the reactants and the "***lost mass***" is converted to ***energy***. Fusion occurs on the ***sun*** (and other stars). Forcing small nuclei to fuse requires huge amounts of energy; however, when fusion reactions occur on the sun, more energy is released than the amount of energy required to produce the reaction. Using fusion for nuclear power plants is still in the developmental stage. A hydrogen bomb, also called a thermonuclear bomb, utilizes nuclear fusion.

Nuclear consequences - define negative ***and*** those that are positive. Nuclear decay occurs naturally in many elements that are common on earth, and there is always some radiation present in every environment. The degree to which radiation is harmful to living organisms depends upon the ***type*** of radiation and the ***quantity*** of radiation to which the organism is exposed.

Nuclear medicine - radioactive materials are widely used in medical technologies.
Benefit examples include: destroys targeted cells such as cancer cells; maps (using radioactive tags/tracers) the path of various substances through the body.
Drawback examples include: nuclear waste must be stored in a special way until it is no longer radioactive. Radiation treatment directed at cancerous cells will also cause some damage to healthy tissue; newer radiation treatments seek to minimize the damage to the healthy tissue while still destroying the cancerous tissue.
Nuclear weapons - fission and fusion nuclear reactions can be used in weapons.
Benefits may include: some people believe that nuclear weapons are a deterrent to war.
Possible drawbacks include: specialized technology is required to refine the fuel and to produce the weapons; tremendous amounts of energy available from small amounts of fuel so smuggling is possible; tremendous amount of destruction both material and biological; contamination of the environment with fission-product isotopes and remains radioactive for very long periods of time; special handling of waste; improper handling of nuclear materials and possible leakage can cause radioactive isotopes to contaminate the environment, causing long-term radioactive decay problems.
Nuclear power reactors - used to produce electricity. Energy from controlled nuclear fission is used to heat water into ***steam***, the steam then expands turns a ***turbine*** and spins a huge magnet within a coil of metal wire. The moving ***magnetic field*** forces electrons to flow in the metal wire.
(Potential) ***benefits*** include: tremendous amounts of energy available from small amounts of fuel, no greenhouse gas/air pollution from the burning of fossil fuels (e.g. in comparison to coal fired power stations); can be used anywhere (as opposed to wind power, solar power, hydroelectric power, etc); abundance of fuel; non-reliance on fossil fuel.
(Potential) ***drawbacks*** include: requires specialized technology to refine the fuel; cause thermal pollution to water systems; waste from nuclear fission reactors must be stored in a special way until it is no longer radioactive, which can be a very long time; nuclear waste must be transported from where it is generated to where it will be stored which very often involves passing through populated areas; improper handling of nuclear materials and possible leaks can cause radioactive isotopes to contaminate the environment, causing long-term radioactive decay problems; accidents in poorly designed or poorly maintained facilities such as Chernobyl or Three Mile Island; exposure of workers in nuclear facilities to radiation.