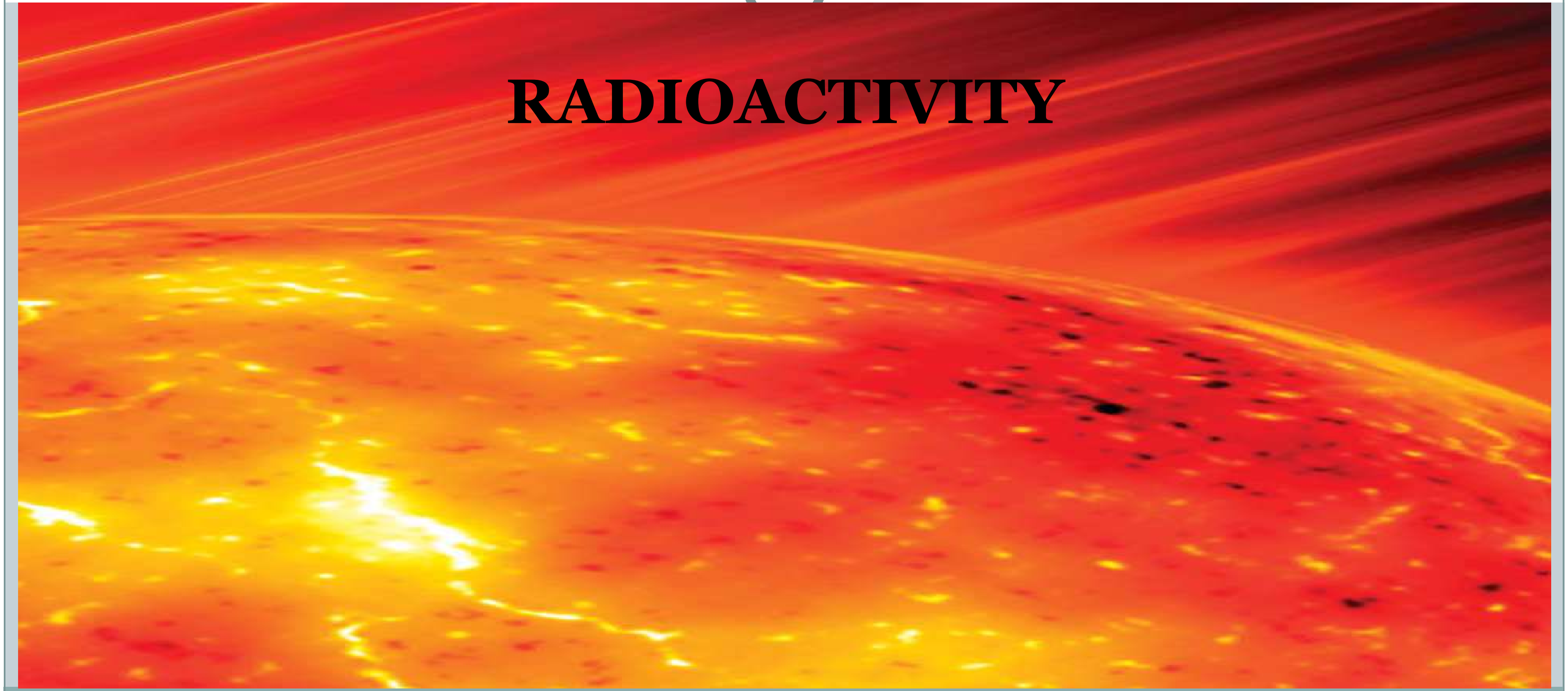
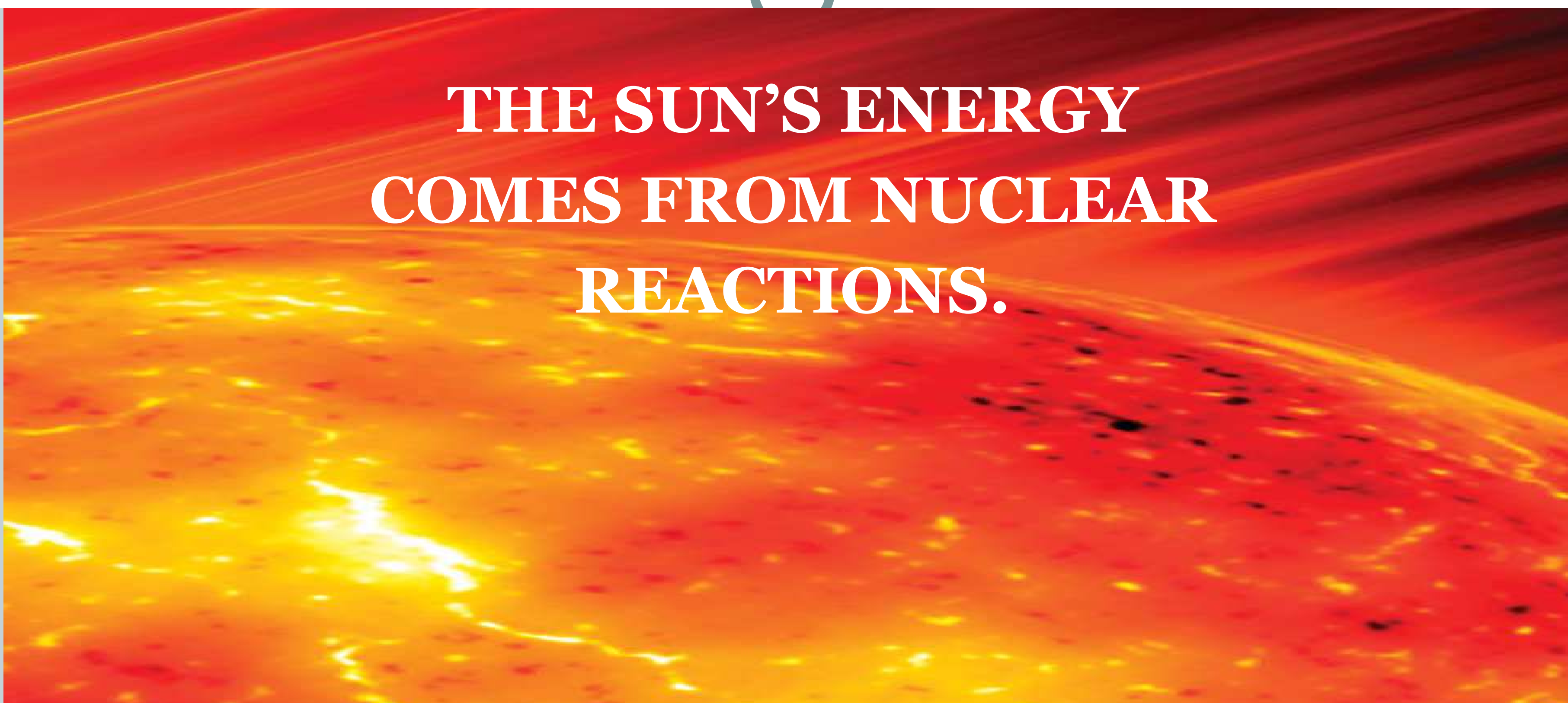
Radioactivity and Nuclear Energy



Radioactivity



Radioactivity

We learned in earlier how the atomic model was discovered through multiple experiments.

We learned that the **electrons** of the atom determine its chemical properties (how it reacts with and forms compounds with other elements)

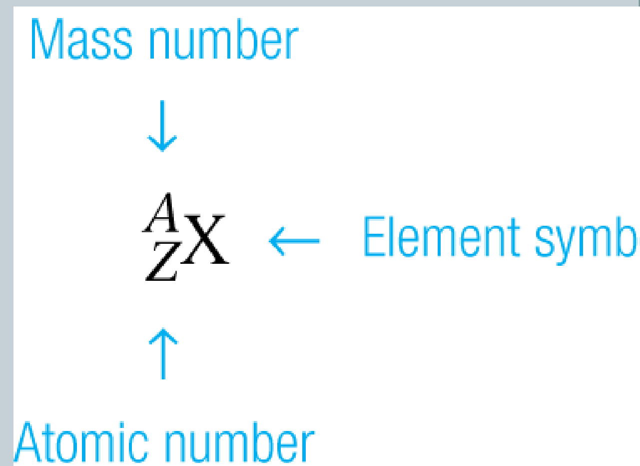
We also learned that the **nucleus** contains **protons** which determine which element the atom is. **Neutrons** are also contained in the nucleus of the atom.

We will discover in this topic, that some elements are unstable and give off nuclear particles that can impact our lives. This is called **radioactivity**.

Radioactivity

Atomic Terms

- nucleons – particles found in the nucleus of an atom
  - neutrons
  - protons
- atomic number (Z) – number of protons in the nucleus
- mass number (A) – sum of the number of protons and neutrons
- isotopes – atoms with identical atomic numbers but different mass numbers
- nuclide – each unique atom



Radioactive Decay

- radioactive – nucleus which spontaneously decomposes forming a different nucleus and producing one or more particles

Many nuclei are **radioactive; that is, they spontaneously decompose**, forming a different nucleus and producing one or more particles.

Types of Radioactive Decay

- Alpha-particle production
- Alpha particle – helium nucleus
  - Examples

$$^{222}_{88}\text{Ra} \rightarrow {}^{4}_{2}\text{He} + {}^{218}_{86}\text{Rn}$$

- <u>**Net effect is loss of 4 in mass number and loss of 2 in atomic number.**</u>

Types of Radioactive Decay

- Beta-particle production
  - Beta particle – electron
    - Examples

$$^{234}_{90}\mathrm{Th} \rightarrow \, ^{234}_{91}\mathrm{Pa} + \, ^{0}_{-1}\mathrm{e}$$

$$^{131}_{53}\mathrm{I} \rightarrow \, ^{0}_{-1}\mathrm{e} + \, ^{131}_{54}\mathrm{Xe}$$

- **Net effect is to change a neutron to a proton.**

Types of Radioactive Decay

- Gamma ray release
- Gamma ray – high energy photon
  - Example

$$^{238}_{92}\text{U} \rightarrow {}^{4}_{2}\text{He} + {}^{234}_{90}\text{Th} + 2\,^{0}_{0}\gamma$$

- **Net effect is no change in mass number or atomic number.**

Types of Radioactive Decay

- Positron production
  - Positron – particle with same mass as an electron but with a positive charge
    - Examples

$$^{22}_{11}\mathrm{Na} \rightarrow {}^{0}_{1}\mathrm{e} + {}^{22}_{10}\mathrm{Ne}$$

- **Net effect is to change a proton to a neutron**.

Types of Radioactive Decay

- Electron capture
  - Example

$$^{201}_{80}\mathrm{Hg} + {}^{0}_{-1}\mathrm{e} \rightarrow {}^{201}_{79}\mathrm{Au} + {}^{0}_{0}\gamma$$

Inner-orbital electron

Types of Radioactive Decay

Summary

Table 19.1

Various Types of Radioactive Processes

Process	Example
β-particle (electron) production	$^{227}_{89}Ac \rightarrow ^{227}_{90}Th + ^{0}_{-1}e$
positron production	$^{13}_{7}N \rightarrow ^{13}_{6}C + ^{0}_{1}e$
electron capture	$^{73}_{33}As + ^{0}_{-1}e \rightarrow ^{73}_{32}Ge$
α-particle production	$^{210}_{84}Po \rightarrow ^{206}_{82}Pb + ^{4}_{2}He$
γ-ray production	excited nucleus → ground-state nucleus + $^{0}_{0}\gamma$ excess energy / lower energy

Nuclear Transformations

- Nuclear transformation – change of one element to another
- Bombard elements with particles

– Examples

In 1919 Lord Rutherford observed the first **nuclear transformation,** *the change of one element into another. He found that bombarding* $^{14}_{7}N$ with particles produced the nuclide $^{17}_{8}O$

$$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$$

$$^{27}_{13}Al + ^{4}_{2}He \rightarrow ^{30}_{15}P + ^{1}_{0}n$$

Fourteen years later, Irene Curie and her husband Frederick Joliot observed a similar transformation from aluminum to phosphorus

Nuclear Transformations

- Transuranium elements – elements with atomic numbers greater than 92 which have been synthesized

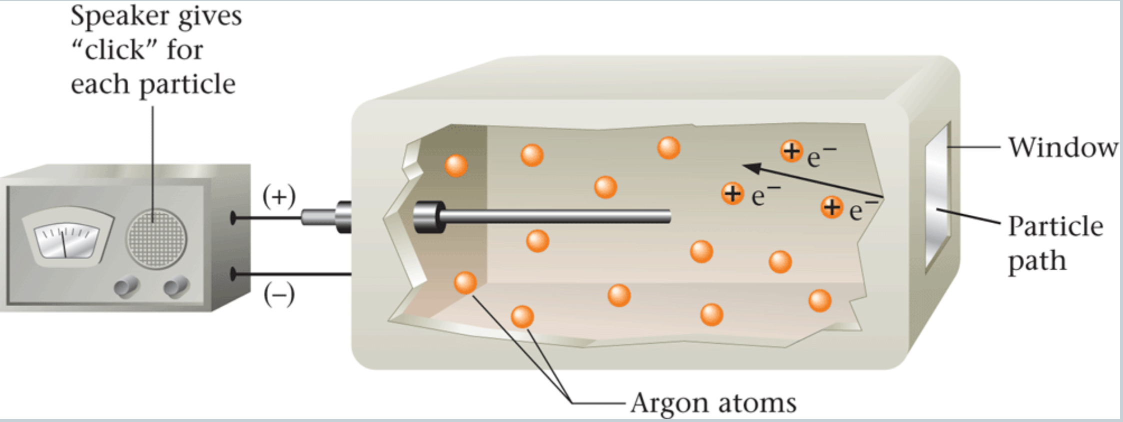
Table 19.2

Syntheses of Some of the Transuranium Elements

Neutron Bombardment	neptunium ($Z = 93$)	$^{238}_{92}U + ^{1}_{0}n \rightarrow ^{239}_{92}U \rightarrow ^{239}_{93}Np + ^{0}_{-1}e$
	americium ($Z = 95$)	$^{239}_{94}Pu + 2\,^{1}_{0}n \rightarrow ^{241}_{94}Pu \rightarrow ^{241}_{95}Am + ^{0}_{-1}e$
Positive-Ion Bombardment	curium ($Z = 96$)	$^{239}_{94}Pu + ^{4}_{2}He \rightarrow ^{242}_{96}Cm + ^{1}_{0}n$
	californium ($Z = 98$)	$^{242}_{96}Cm + ^{4}_{2}He \rightarrow ^{245}_{98}Cf + ^{1}_{0}n$ or
		$^{238}_{92}U + ^{12}_{6}C \rightarrow ^{246}_{98}Cf + 4\,^{1}_{0}n$
	rutherfordium ($Z = 104$)	$^{249}_{98}Cf + ^{12}_{6}C \rightarrow ^{257}_{104}Rf + 4\,^{1}_{0}n$
	dubnium ($Z = 105$)	$^{249}_{98}Cf + ^{15}_{7}N \rightarrow ^{260}_{105}Db + 4\,^{1}_{0}n$
	seaborgium ($Z = 106$)	$^{249}_{98}Cf + ^{18}_{8}O \rightarrow ^{263}_{106}Sg + 4\,^{1}_{0}n$

Detection of Radioactivity and Half-Life

- Geiger-Muller counter – instrument which measures radioactive decay by registering the ions and electrons produced as a radioactive particle passes through a gas-filled chamber



- Scintillation counter – instrument which measures the rate of radioactive decay by sensing flashes of light that the radiation produces in the detector

Detection of Radioactivity and Half-Life

- Half-life – time required for half of the original sample of radioactive nuclides to decay

For example, if a certain radioactive sample contains 1000 nuclei at a given time and 500 nuclei (half of the original number) 7.5 days later, this radioactive nuclide has a half-life of 7.5 days

Table 19.3

The Half-lives for Some of the Radioactive Nuclides of Radium

Nuclide	Half-life
$^{223}_{88}Ra$	12 days
$^{224}_{88}Ra$	3.6 days
$^{225}_{88}Ra$	15 days
$^{226}_{88}Ra$	1600 years
$^{228}_{88}Ra$	6.7 years

- The end