NUCLEAR POWER FISSION OR FUSION

PRESENTED BY ANDREW OHRABLO AND KRISTINE GEHRING-OHRABLO

BIO

- Andrew Ohrablo
  - Bachelor of Science Nuclear Engineering – University of Wisconsin at Madison
    - Senior Thesis – Design of Liquid Metal Fast Breeder Reactor
  - Perry Nuclear Power Plant, Perry, OH 2014-Present
    - Supervisor Maintenance Engineering- Current Position
    - Maintenance Electrical Engineer
    - Work Week Manager
  - Cooper Nuclear Station, Brownville, NE 1999-2014
    - Shift Technical Engineer
    - Senior Reactor Operator NRC License Number 44337
  - United States Navy Nuclear Electrician – USS Enterprise 1987-1993

BIO

- Kristine Gehring-Ohrablo
  - Masters of Science Radiation Health Physics – Oregon State University
  - Masters of Science Bacteriology – University of Wisconsin at Madison
  - Bachelors of Science Microbiology – Ohio State University
  - Perry Nuclear Power Plant, Perry, OH 2014-present
    - Primary Chemist
  - Cooper Nuclear Station, Brownville, NE 2000-2014
    - Staff Chemist
    - Chemistry Technician

BASIC DEFINITIONS

- Fission – Splitting of the nucleus of a large atom into smaller atoms accompanied by a large release of energy.
- Fusion – Thermonuclear reaction where two light nuclei are combined to form a heavier nuclei with the release of energy.

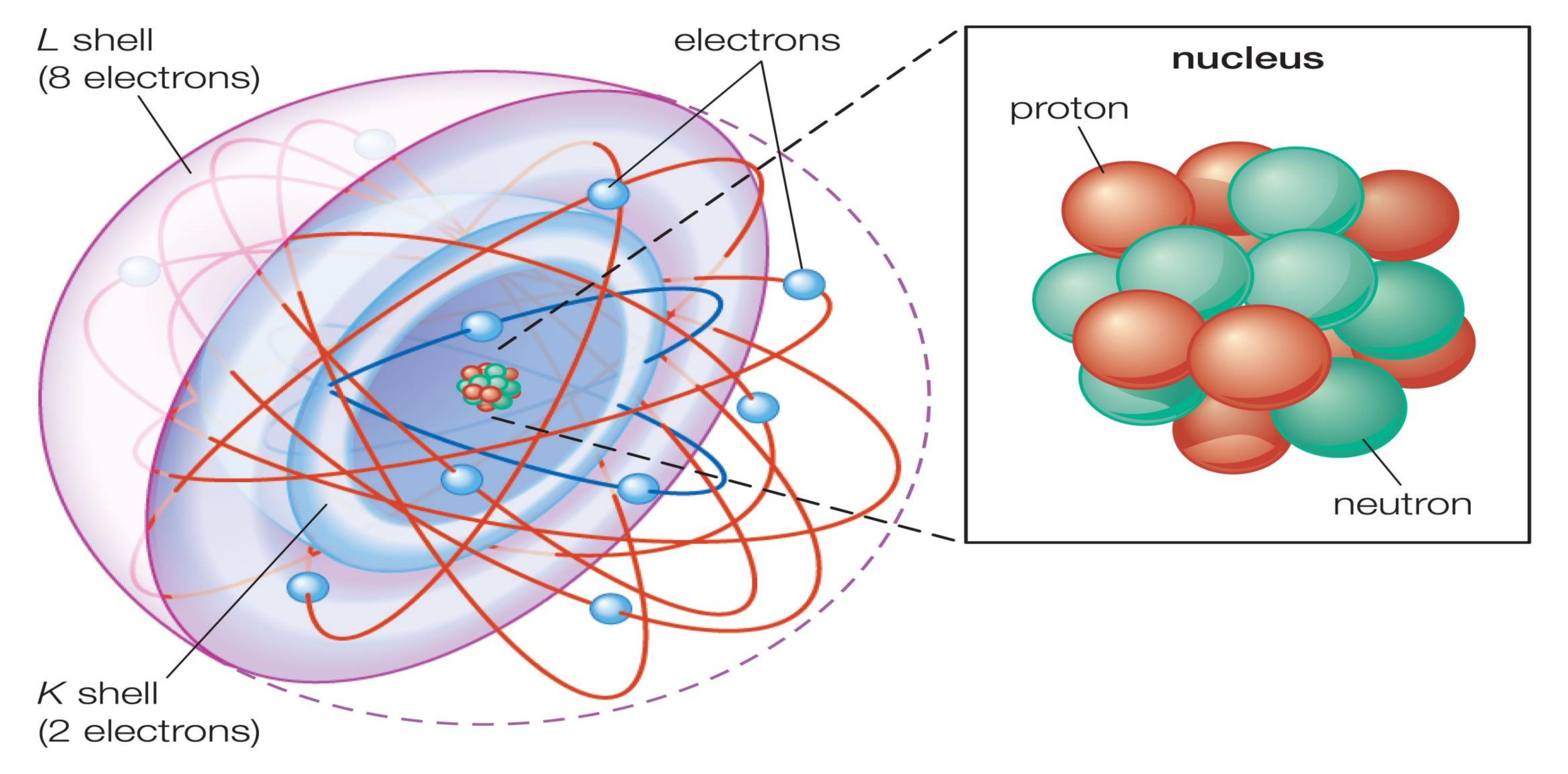
FORCES ASSOCIATED WITH THE INTERNALS OF AN ATOM

- Two forces are at play inside the atom, the nuclear force and magnetic repulsion
- Nuclear force
  - Very powerful force of attraction
  - Very short range
- Magnetic repulsion
  - Significantly weaker force then the nuclear force
  - Range of Repulsion much larger than the nuclear force

PARTS OF THE ATOM

- Nucleon – subatomic particle located in the nucleus of an atom – either a neutron or proton
- Proton – positively charged subatomic particle, mass is ~1 atomic mass unit (amu)
- Neutron - uncharged subatomic particle, mass is ~1amu
- Electron – negatively charged particle that orbits the nucleus, when compared to a nucleon, effectively massless
- *1amu = 1/12 of a Carbon-12 atom

MODEL OF THE ATOM



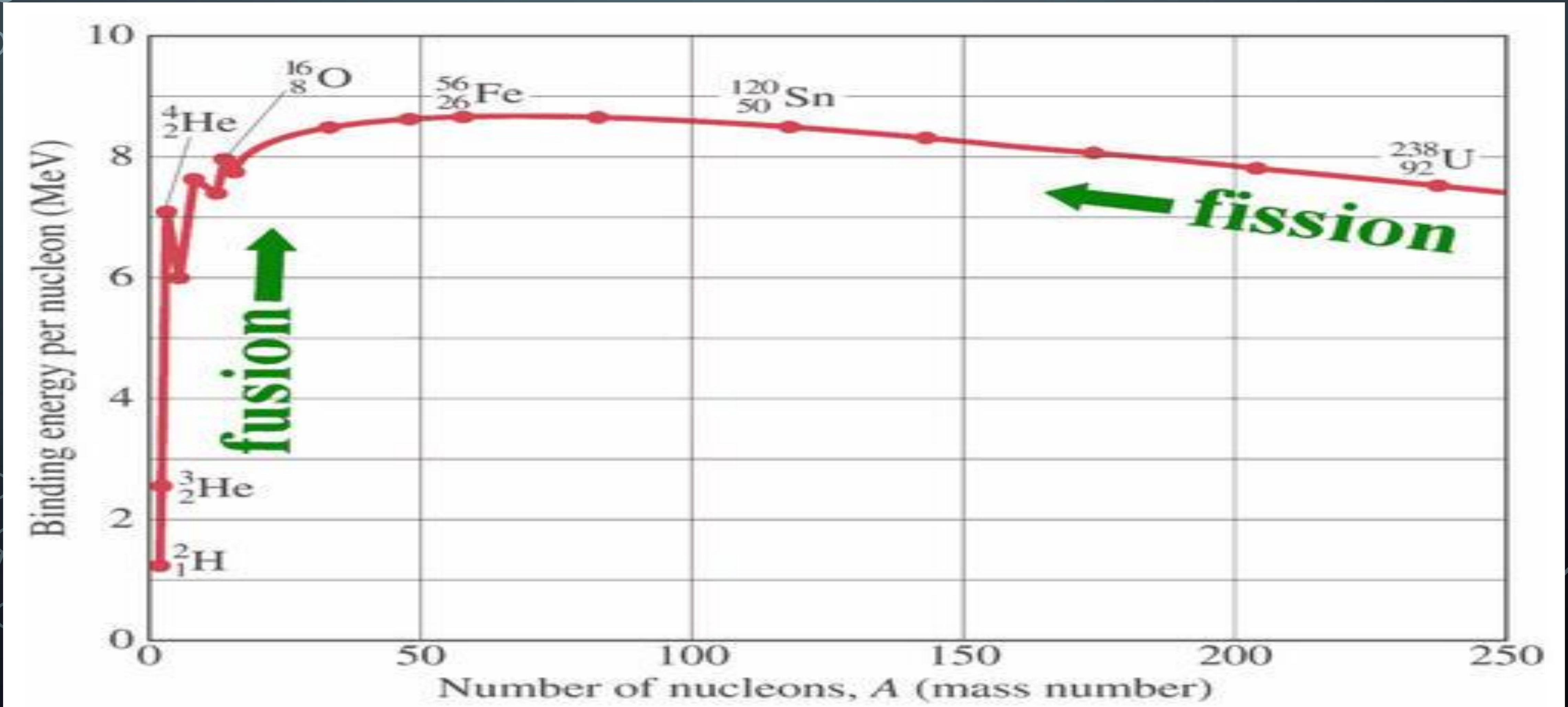
MASS DEFECT AND BINDING ENERGY

- Mass Defect – Difference between the mass of the parts of the atom when individually added up and the mass of the nucleus of the atom when assembled.
- Example using Helium 4 atom – 2 protons and 2 neutrons
  - Proton mass x 2 = 1.00727647amu x 2 = 2.01455294 amu
  - Neutron mass x 2 = 1.08866490 x 2 = 2.0173298 amu
  - Total of parts = 4.0318824
  - Actual measured mass = 4.00150608 amu
  - Mass Defect = parts – actual = 0.03037666 amu

BINDING ENERGY

- Binding Energy (BE) – Energy equivalent of the mass defect using Einstein's formula of $E = mc^2$
- BE = [(# protons) x (mass of a proton) + (# neutrons) x (mass of a neutron) - (mass of the nucleus)] x c^2
- C = 2.998E8 m/sec (speed of light)
- c^2 converted to MeV/amu = 931.48 MeV/amu
- From example of He-4:
  - BE = 0.03037666 amu x 931.48 MeV/amu = 28.2952 MeV

BINDING ENERGY PER NUCLEON



PHYSICS

- The attractive nuclear force is very short, measured in femtometers (1E-15 m)
- Atoms are measured in Angstroms (1E-10 m)
- For small atoms, BE/nucleon goes up as nucleons are added because all nucleons can be close and partake of the nuclear forces
- For larger atoms, nuclear force is not shared by all nucleons and the BE/nucleon goes down.
- For larger atoms, instability occurs when the electrostatic repulsion can overcome the nuclear forces.

ENERGY GENERATION

- Energy released is the difference between the binding energies of the initial parts as compared to the binding energies of the final parts.
- In fusion we move from the bottom left upwards.
- In fission we move from the right to the left.

FISSION GENERAL PROCESS

- Fuel rods contain U-235 and U-238.
- Fuel is bombarded with slow neutrons.
- U-235 can spontaneously fission .
- U-238 captures a neutron and through beta decay turns into P-239 which can then fission when it absorbs a neutron.
- This results in more neutrons for the next generation and a chain reaction.
- Heat from fission is transmitted to the coolant .
- The coolant is used to produce steam, and the steam turns a generator.

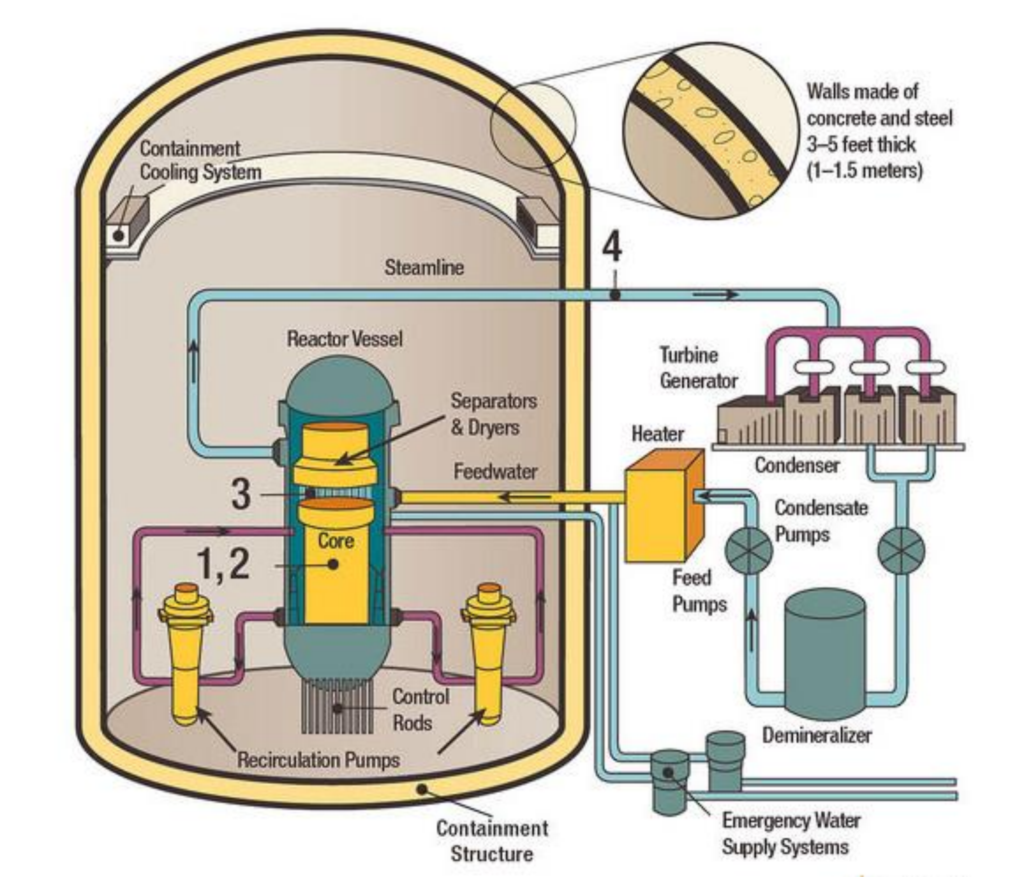
BOILING WATER REACTORS

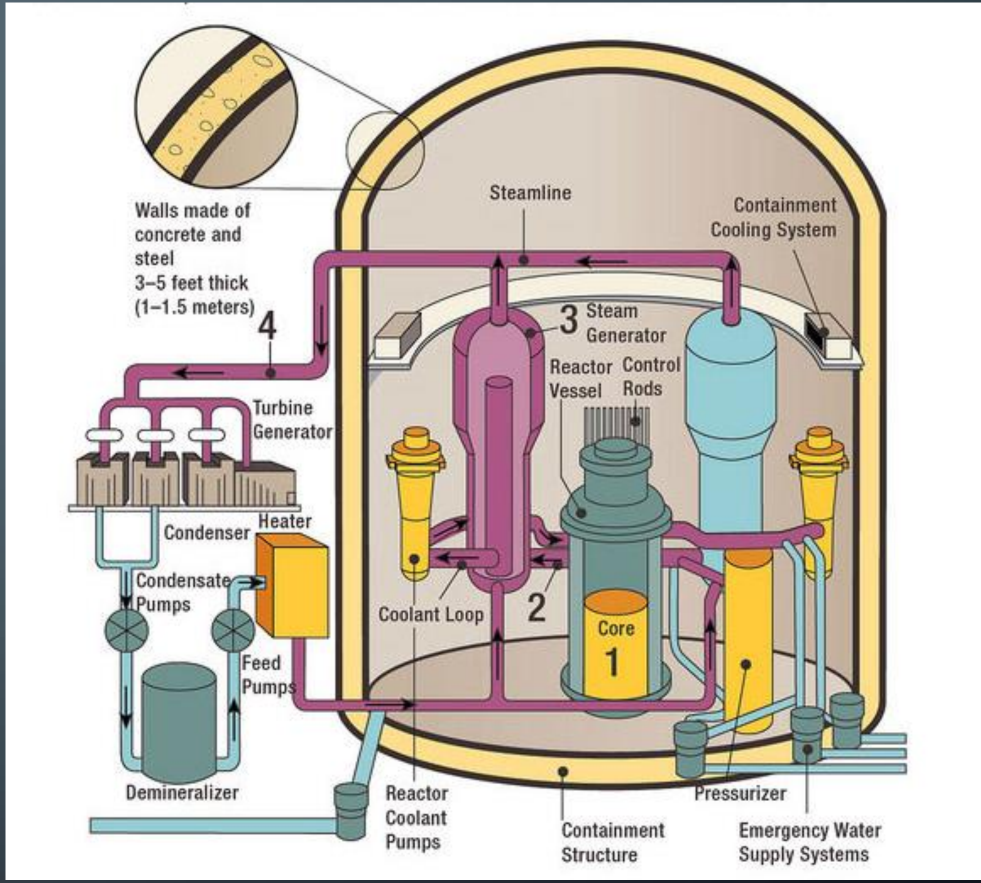
- Normal operating pressure around 1000 psig.
- Reactivity (power) controlled by control rod position or reactor coolant flow.
- Cooling water is also heat transfer medium.

PRESSURIZED WATER REACTOR

- Reactor Pressure can be around 2000 psig.
- Reactivity (power) controlled by boron concentration.
- Primary coolant never exits containment structure – lower dose .

NUCLEAR REACTOR TYPES





NORMAL OPERATING PRESSURE AROUND 1000 PSIG.

REACTIVITY (POWER) CONTROLLED BY CONTROL ROD POSITION OR REACTOR COOLANT FLOW.

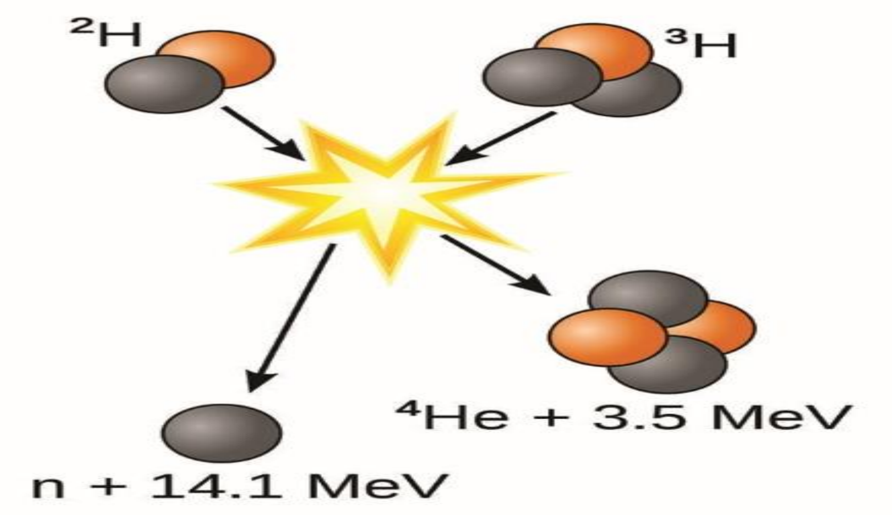
COOLING WATER IS ALSO HEAT TRANSFER MEDIUM.

REACTOR PRESSURE CAN BE AROUND 2000 PSIG.

REACTIVITY (POWER) CONTROLLED BY BORON CONCENTRATION.

PRIMARY COOLANT NEVER EXITS CONTAINMENT STRUCTURE – LOWER DOSE

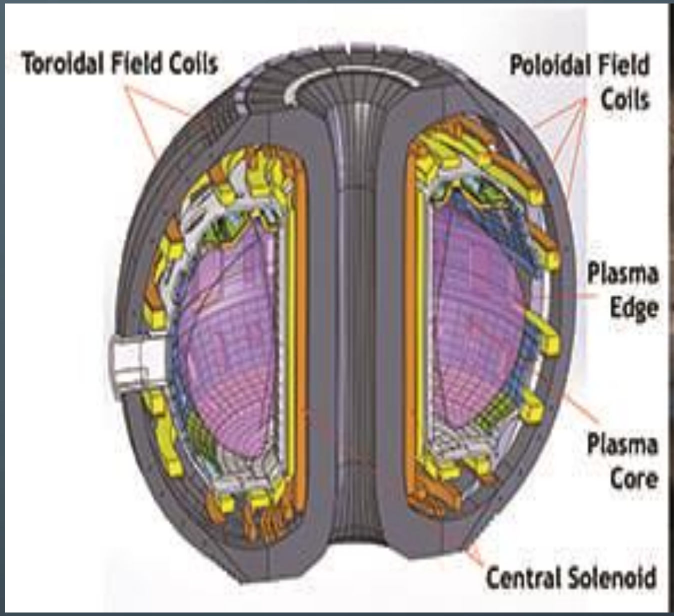
FUSION GENERAL PROCESS



Fusion is a nuclear reaction in which two or more atomic nuclei combine to form one or more different atomic nuclei and often subatomic particles as well.

Tokamak "Toroidal Confinement Machine"

- Vessel for magnetic containment of plasma
- Plasma is superheated
- Fusion occurs between light elements



Heat is removed by helium cooling in the lithium blankets that surround the plasma

GEH BWRX-300

FISSION

Benefits

- Known technology
- Currently operational
- High Capacity Factors

Detriments

- Nuclear waste
- Finite uranium supply
- Public perception associated with nuclear weapons
- Breeder reactors can generate weapons-grade transuranics

FUSION

Benefits

- No negative connotations with nuclear weapons
- Very little contamination/ nuclear waste
- Nearly limitless supply of fuel

Detriments

- Never achieved positive energy release
- Physics to generate electricity not demonstrated
- Magnetic containment limits amount of fuel load available
- Future technology, eta 2040 for commercial operation

QUESTIONS?

TERMS

- Critical – status of nuclear reactor where the number of neutrons in one generation is equal to the number of neutrons in the previous generation – power is remaining constant
- Reactivity – Relative departure from critical for a nuclear reactor
- Sub-Critical – status of nuclear rector where the number of neutrons in one generation is less than the number of neutrons in the previous generation – power is going down
- Super-Critical – status of nuclear rector where the number of neutrons in one generation is greater than the number of neutrons in the previous generation – power is going up
- Barns – measure of cross section of a nucleus for a specific reaction – higher barns means a nucleus is more likely to react

TERMS (CONTINUED)

- Absorption – nuclear reaction where an incident particle is absorbed into the nucleus
- Capture – nuclear reaction where an incident particle remains in the nucleus following absorption
- Fission – nuclear reaction where an incident particle results in the parent nucleus splitting into two or more nuclei
- Beta Decay – radioactive decay where an excited nucleus releases energy in the form of a positron or electron and a nucleon is changed from a proton or neutron to bring the nucleus to a lower energy state
- Alpha decay – where an excited nucleus releases an alpha particle to bring the nucleus to a lower energy state
- Alpha Particle – Essentially a helium atom without the electrons. Two protons and two Neutrons

COEFFICIENTS OF POWER

- A coefficient of power is a change in the physical properties of the reactor and how it affects the neutron life cycle
- A positive coefficient of power will result in a rise in neutron population from one generation to the next. A power increase.
- Coefficients of power are affected by
  - Temperature
  - Pressure
  - Voids
  - Doppler
  - Poisons