Atomic Structure

The nuclear atom

Electron Configuration

Ms. Thompson - SL Chemistry
Wooster High School

Topic 2.1
The nuclear atom

- Atoms contain a positively charged dense nucleus composed of protons and neutrons (nucleons).
- Negatively charged electrons occupy the space outside the nucleus.
- The mass spectrometer is used to determine the relative atomic mass of an element from its isotopic composition.

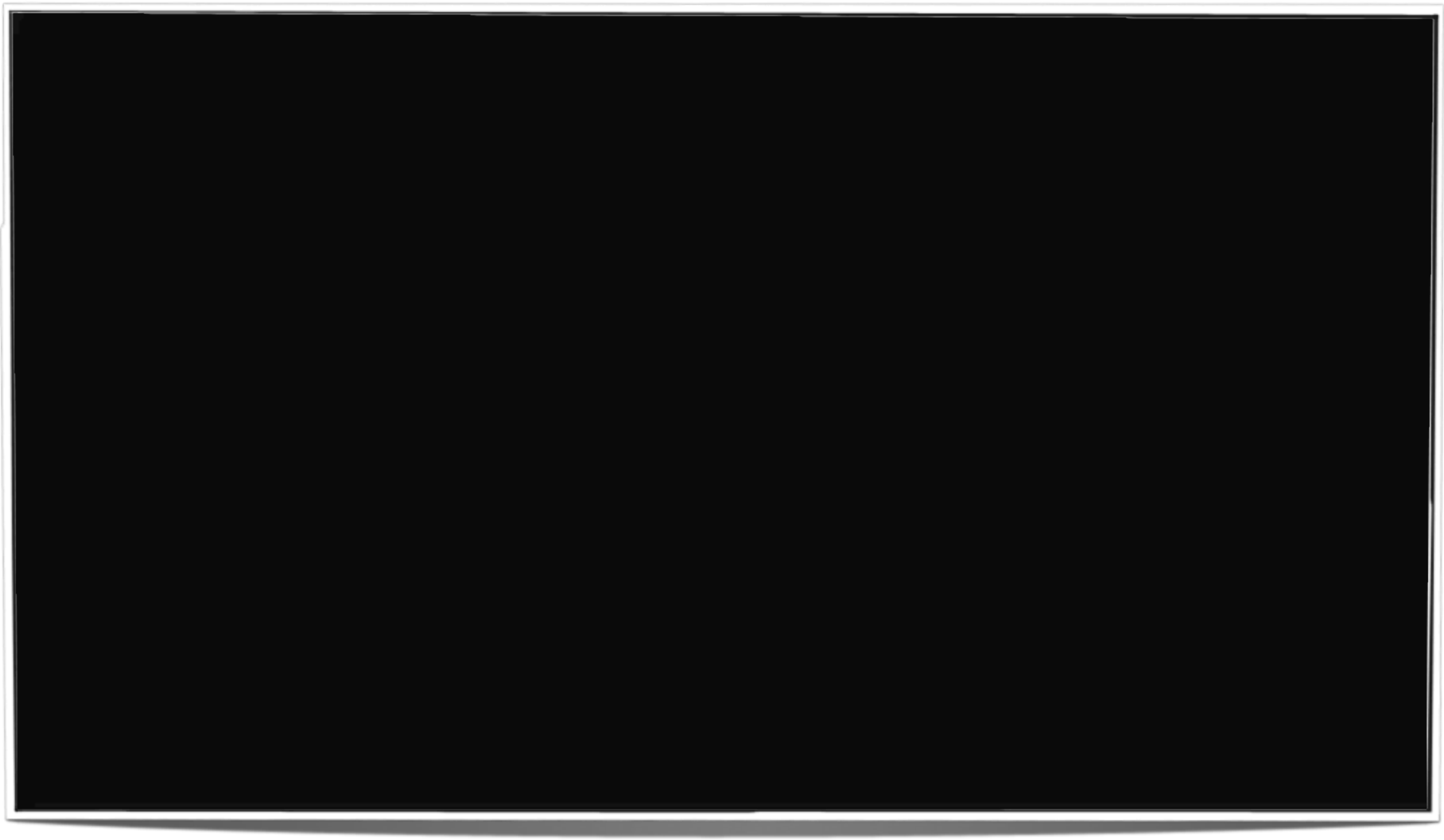
The nuclear atom

Subatomic particles and descriptions of the atom

- Atoms consist of three types of subatomic particle:
  - proton
  - neutron *(discovered by British physicist James Chadwick, 1932)*
  - electron
- Masses are in **atomic mass units (amu)**
  - 1 amu = 1.660539×10^{-24}g

Subatomic Particle	Charge	Mass/amu	Location
proton	+1	~1	nucleus
neutron	0	~1	nucleus
electron	-1	1/1836	outside nucleus in electron cloud

Atomic Structure



The nuclear atom

Subatomic particles and descriptions of the atom

- **The atomic number, Z**
  - Atoms each have their own unique **atomic number, Z**
  - The **atomic number** is the number of *protons* in the nucleus of the atom of an element.
- In a neutral atom (no overall charge) the number of electrons is equal to the number of protons.
  - Z for oxygen is 8, oxygen has 8 protons and 8 electrons
    (-8)+(+8) = 0 (neutral)
- ***The mass number, A***
  - *The mass of the atom comes from the nucleus, which contains the protons and neutrons.*
  - *The **mass number**, A, is the number of protons + number of neutrons*
  - Z for fluorine, F, is 9, fluorine has 9 protons and 9 electrons
  - A for fluorine-19 is 19. Therefore, fluorine has 19-9=10 neutrons

The nuclear atom

Subatomic particles and descriptions of the atom

- The **nuclear symbol** includes both A and Z for a particular element X and is represented like this:

  ${}^{A}_{Z}\mathbf{X}$

- **Isotopes** are different forms of the same element but have different number of neutrons (different mass numbers, A)
  - *Hydrogen has three isotopes:*

  ${}^{3}_{1}\mathbf{H}$ (tritium)
  1 proton, 1 electron, 2 neutrons

  ${}^{2}_{1}\mathbf{H}$ (deuterium)
  1 proton, 1 electron, 1 neutron

  ${}^{1}_{1}\mathbf{H}$ (hydrogen)
  1 proton, 1 electron, 0 neutrons

The nuclear atom

Isotope enrichment: Nuclear energy and nuclear weapons

Uranium found in nature consists of three isotopes with the relative abundances and atomic composition found below:

Isotope	Relative abundance	Number of protons	Number of electrons	Number of neutrons
^{234}U	0.0055%	92 protons	92 electrons	142 neutrons
^{235}U	0.7200%	92 protons	92 electrons	143 neutrons
^{238}U	99.2745%	92 protons	92 electrons	146 neutrons

Uranium-235 is used in nuclear reactors where it undergoes **fission** (splitting) with the release of a large amount of energy. Natural uranium has a much higher abundance of U-238 than U-235 so uranium ore may be **enriched** to increase the proportion of U-235. The separation of natural uranium into enriched uranium and depleted uranium is the physical process of **isotope separation**.

Because they are the same element, the isotopes have the same chemical properties but they show different physical properties due to their different mass numbers.

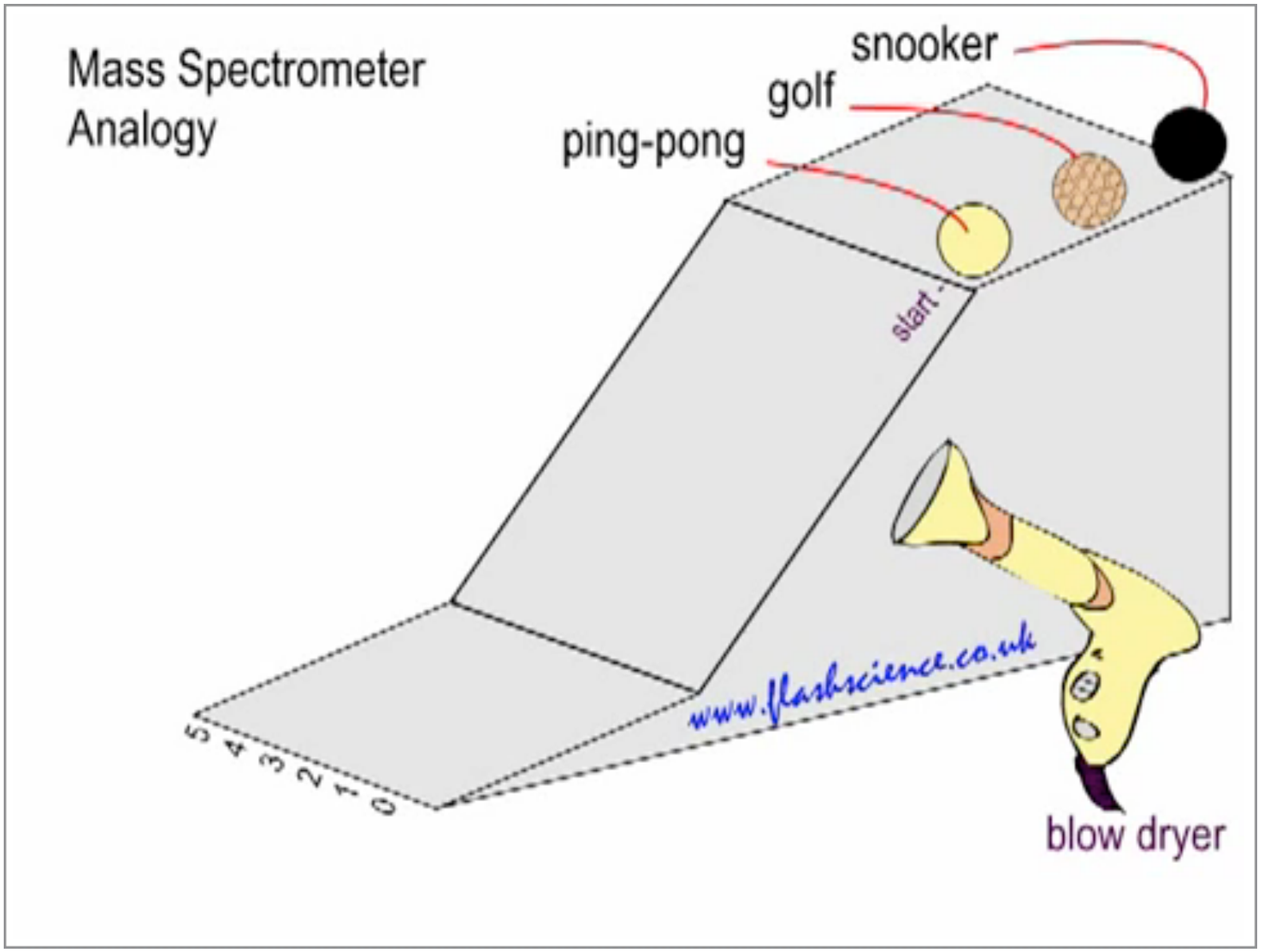
The nuclear atom

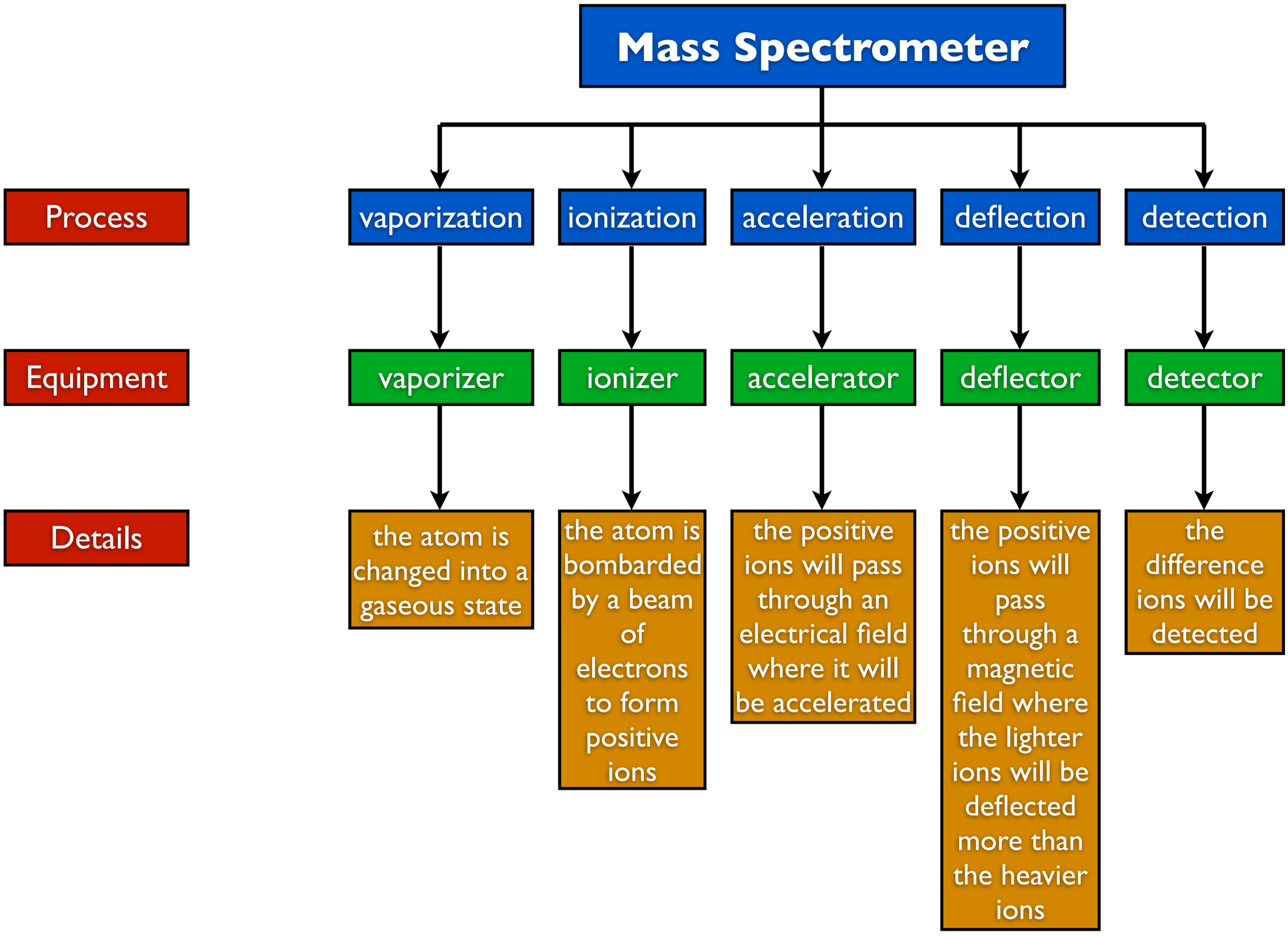
Radioisotopes

- Boron has numerous **radioisotopes** (radioactive isotopes)
  - Boron-10, Boron-11, Boron-8, Boron-9, Boron-12, Boron-13
- Radioisotopes are used in nuclear medicine for diagnostics, treatment, and research.
  - Iodine-131 is used as a tracer for thyroid issues
  - Carbon-14 is used for age determination in archaeology, geology, geophysics, and other branches of science

The nuclear atom

Mass spectrometer




Mass Spectrometer
Process
vaporization
ionization
acceleration
deflection
detection
Equipment
vaporizer
ionizer
accelerator
deflector
detector
Details
the atom is changed into a gaseous state
the atom is bombarded by a beam of electrons to form positive ions
the positive ions will pass through an electrical field where it will be accelerated
the positive ions will pass through a magnetic field where the lighter ions will be deflected more than the heavier ions
the difference ions will be detected

Practice Problem

... I Do ...

Boron has two naturally occurring isotopes with the natural abundances shown below:

Isotope	Natural Abundance/%
^{10}B	19.9
^{11}B	80.1

Calculate the relative atomic mass of boron:

$$\text{relative atomic mass} = (10 \times \frac{19.9}{100}) + (11 \times \frac{80.1}{100}) = 10.8$$

Practice Problem

... We Do ...

Rubidium has a relative atomic mass of 85.47 and consists of two naturally occurring isotopes, ^{85}Rb (u=84.91) and ^{87}Rb (u=86.91). Calculate the percentage composition of these isotopes in a naturally occurring sample of rubidium.

$$A_r = 85.47 = \frac{84.91x + 86.91(100-x)}{100}$$

$85.47 \times 100 = 84.91x + 86.91(100-x)$

$8547 = 84.91x + 8691 - 86.91x$

$-2.00x = -144$

$x = 72.00$

The sample contains 72.00% ^{85}Rb and 28.00% ^{87}Rb

Practice Problem

20 mins

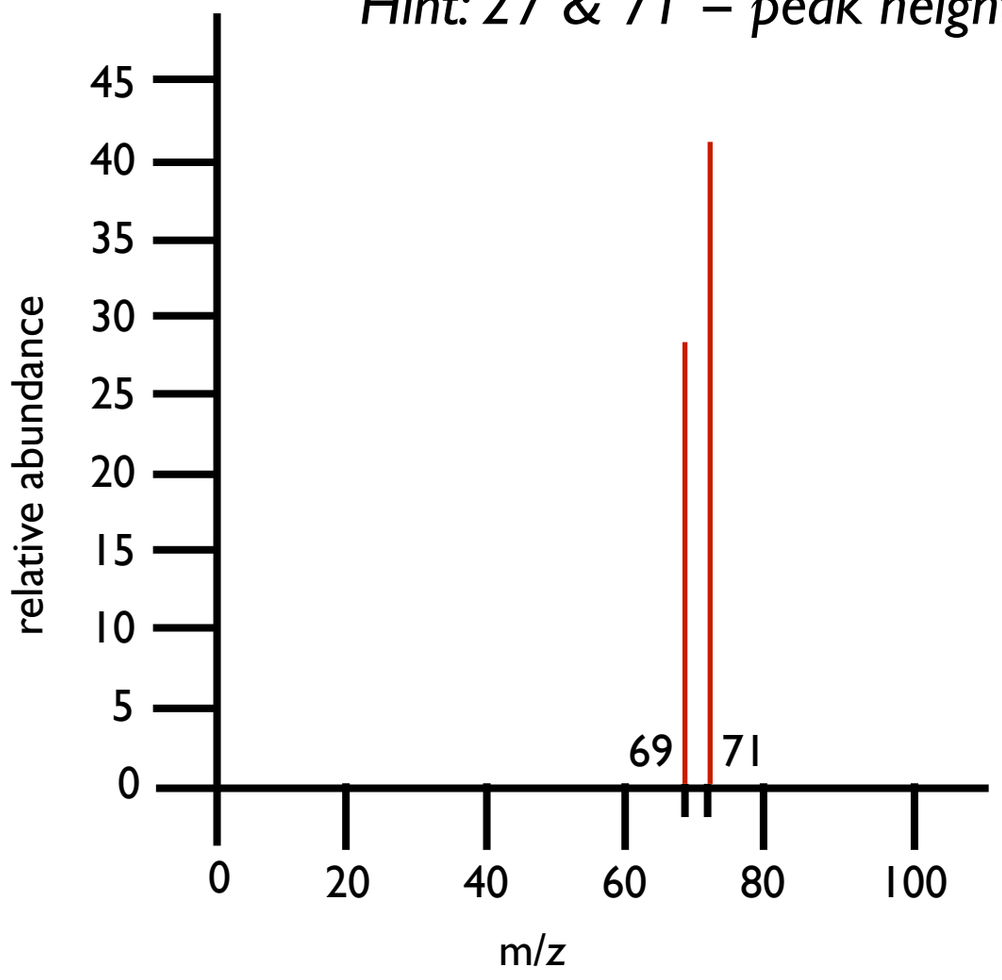
... You Do ...

Work with a partner and answer the following question:

Deduce the relative atomic mass of the element X from its mass spectrum (right) and identify X from the periodic table.

Hint: X-69 and X-71

Hint: 27 & 71 = peak heights



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