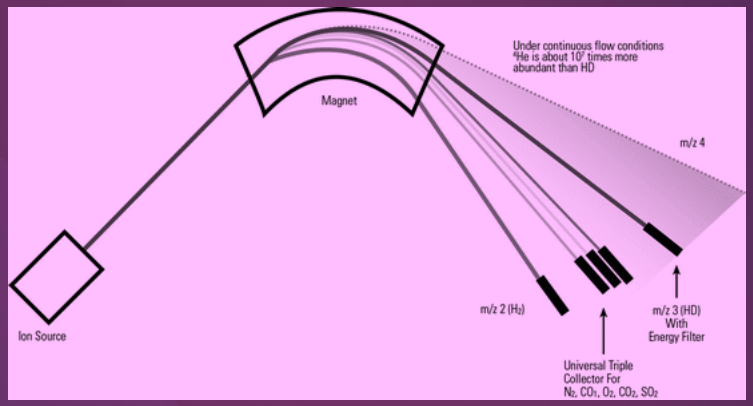
Instrumental Technique

Isotope-ratio mass spectrometry

Understanding compound's origin and history through its isotopic composition



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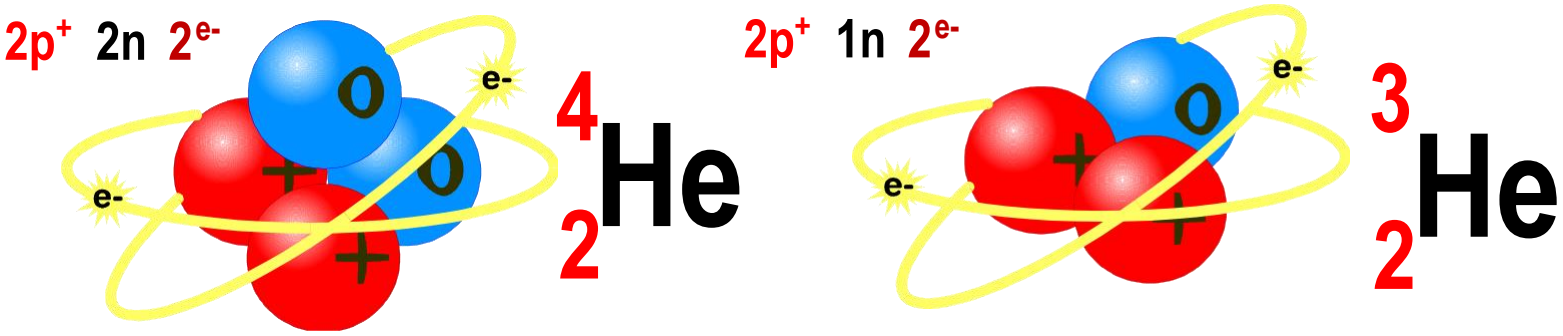
02.06.2018

https://link.springer.com/chapter/10.1007/978-3-319-67903-7_10

What is an isotope?

Frederick Soddy (1877-1956) originated the word *isotope* from the Greek words *isos* meaning "equal" (as in chemically non-separable) and *topos* meaning "place" or of the same place in the periodic table.

An isotope is the same element with the same number of protons but differing number of neutrons.



History: key dates

- **1906** : Thompson received the Nobel Prize for his work on charged particles.
- **1922** : Aston received the Nobel Prize for the discovery of 212 of the naturally occurring isotopes using three generations of mass spectrographs.
- **1930's** : Urey developed the theory of isotope geochemistry and received the Nobel Prize for the discovery of Deuterium.
- **1940's** : Nier developed the first IRMS, a double-focusing double inlet MS.
- **1947** : Jenckel built the first MS at Altlas-Werke AG in Bremen and created a new small division: MAT.
- **1953** : MAT launched the first commercial IRMS.

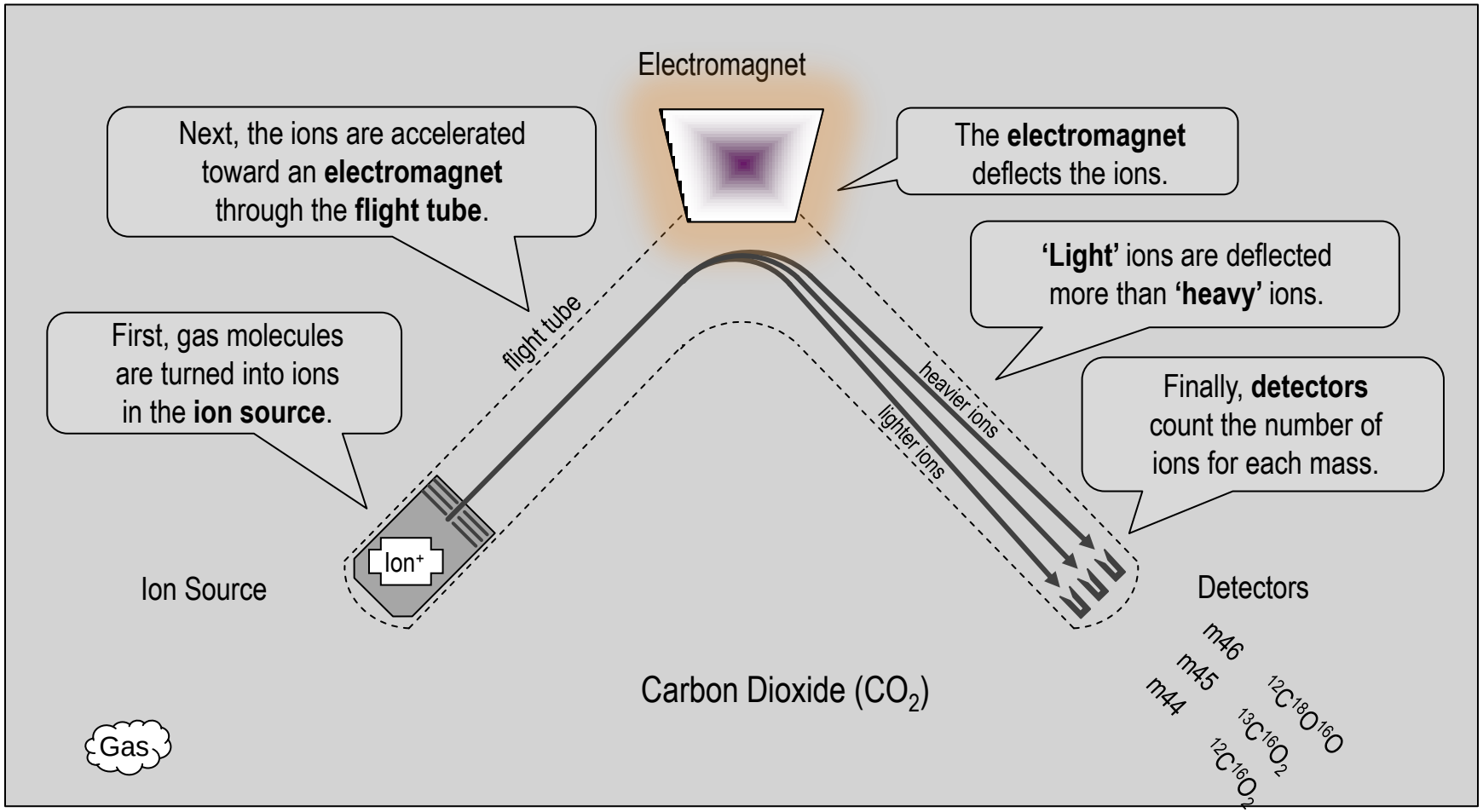
Analytical information from a sample

Quantification:
How Much?

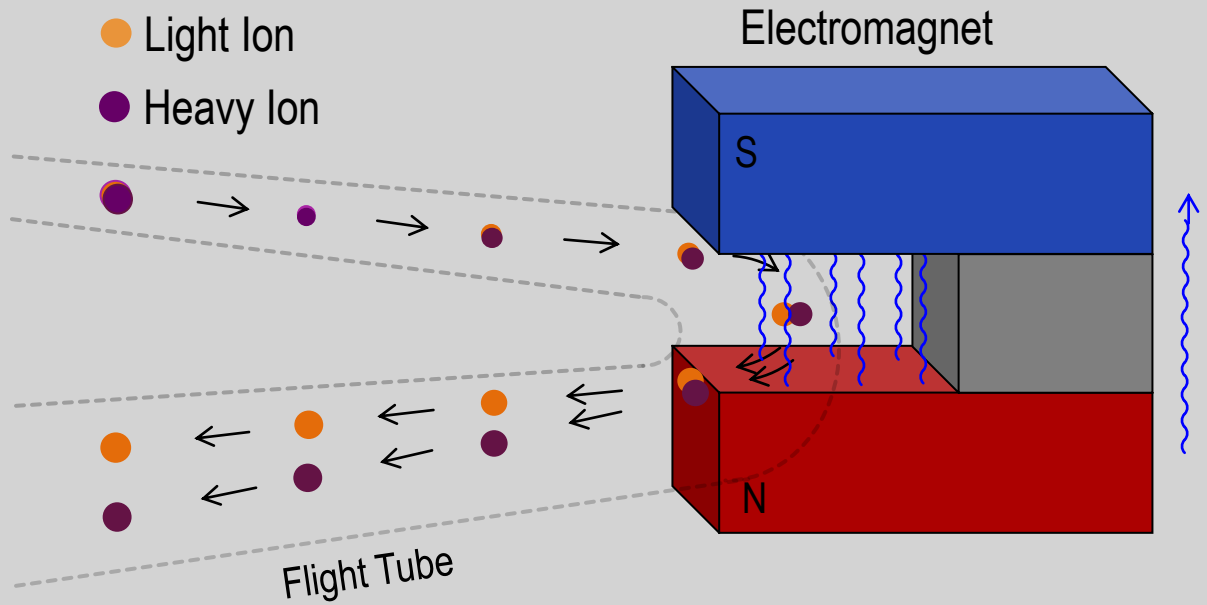
Analysis of the Isotopic Composition:
Source, Origin, Fate?

Substance Identification:
What?

Isotope Ratio Mass Spectrometer



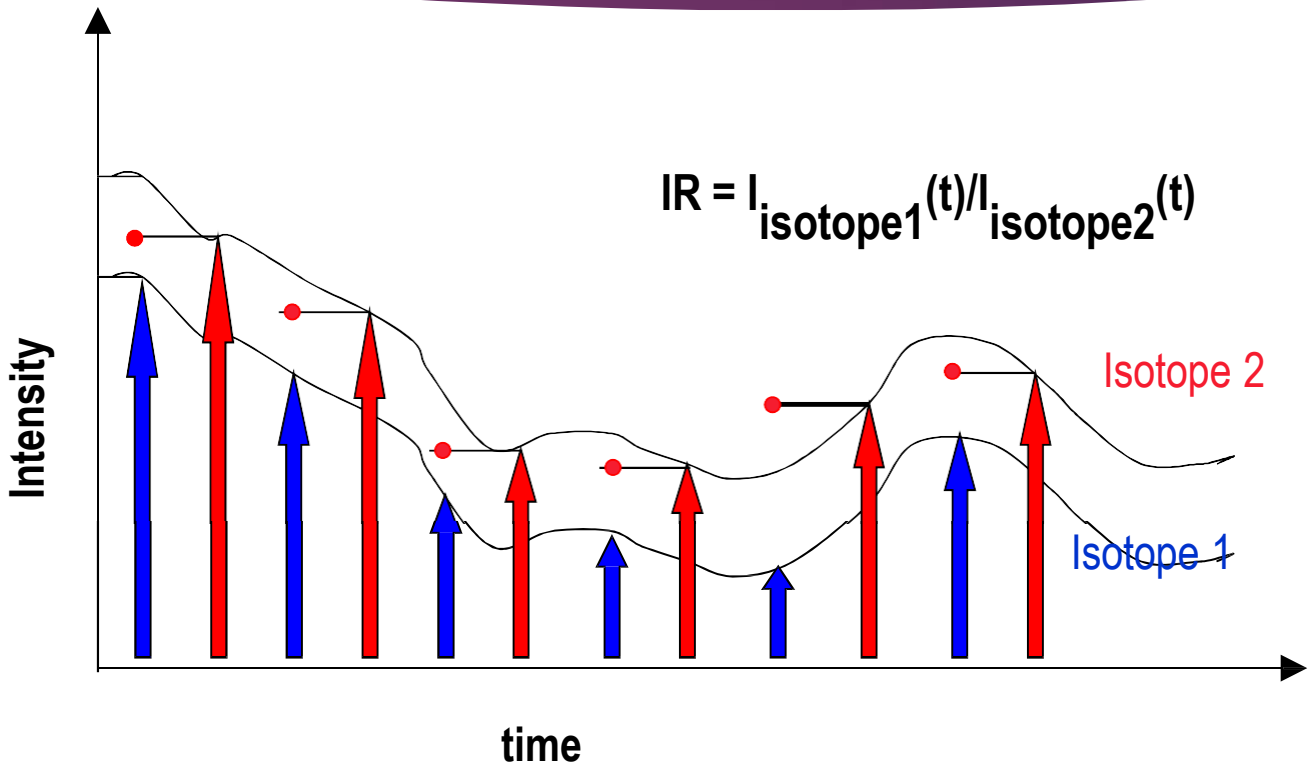
Ion Deflection (Electromagnet)



$$\frac{M}{Z} = \frac{B^2 R^2}{2V}$$

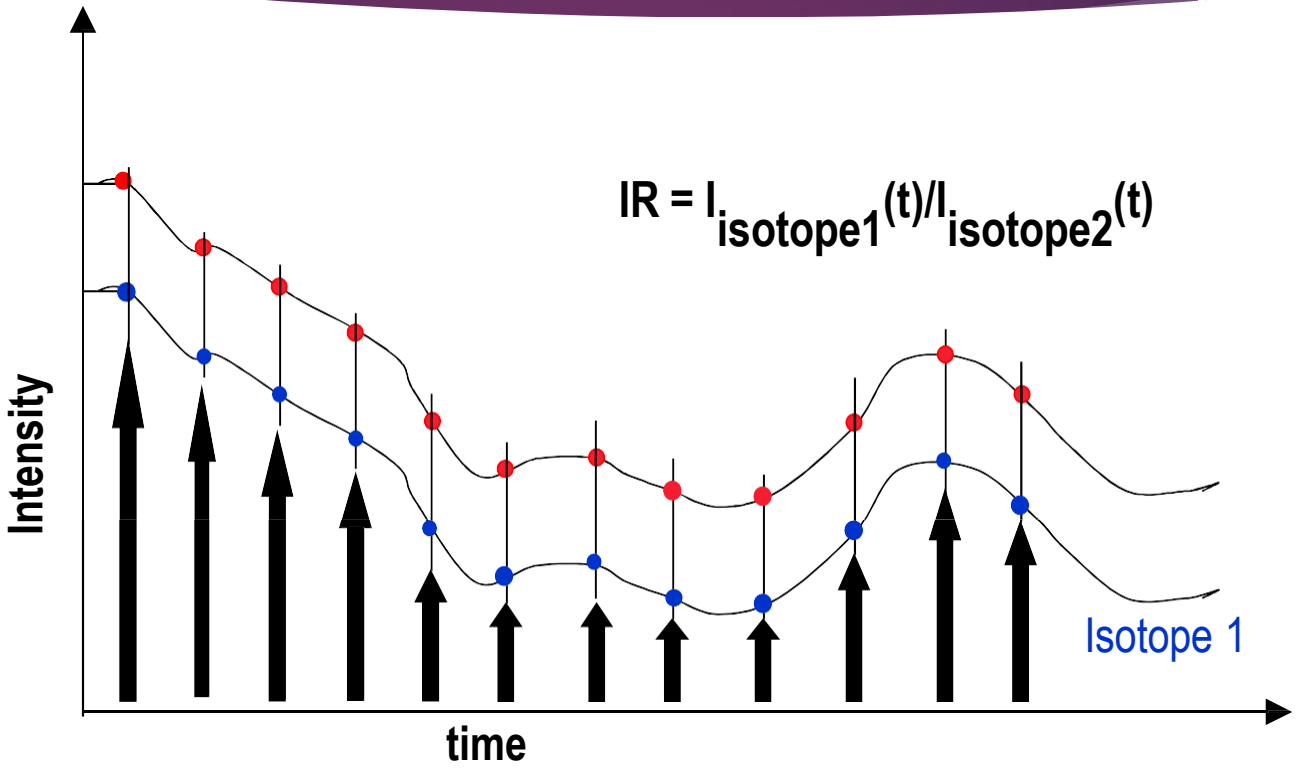
M mass, Z charge
B uniform magnetic field,
V potential
R radius

Why multi-collection?
Sequential measurement of isotopes



Precision and accuracy of the ratio
depend on signal stability

Why multi-collection?
Parallel measurement of isotopes



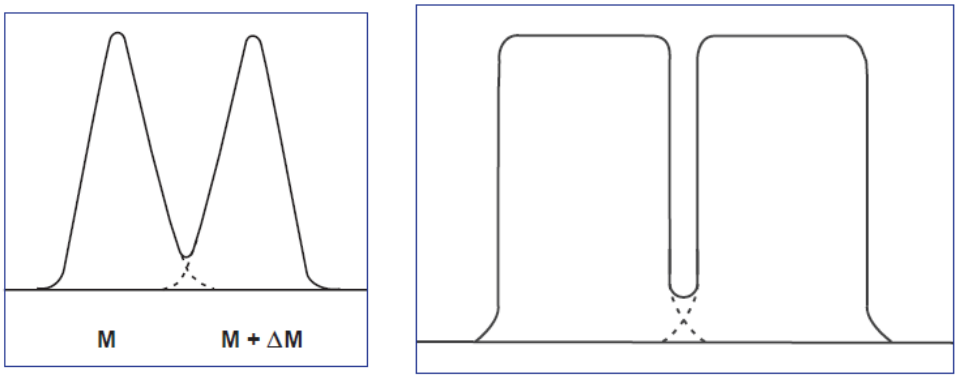
Precision and accuracy of the ratio
independent of signal stability

Peak Shape

A pronounced difference between analytical and isotope ratio instruments lies in the peak shape observed by scanning the magnetic or electric fields.

An analytical instrument provides a spectrum of mass peaks that is characteristic of chemical composition. Very narrow peaks are used to distinguish closely spaced masses.

In isotope ratio work, the chemical composition of the sample is known and the fields are held constant. The variation of isotopes in an element is most precisely measured by using broad peaks.



Flat top peaks are mandatory for high precision isotopic measurements.

Gas source Mass Spectrometry (SIRMS or Gas-IRMS)

On-line or
Off-line

Pure Gas

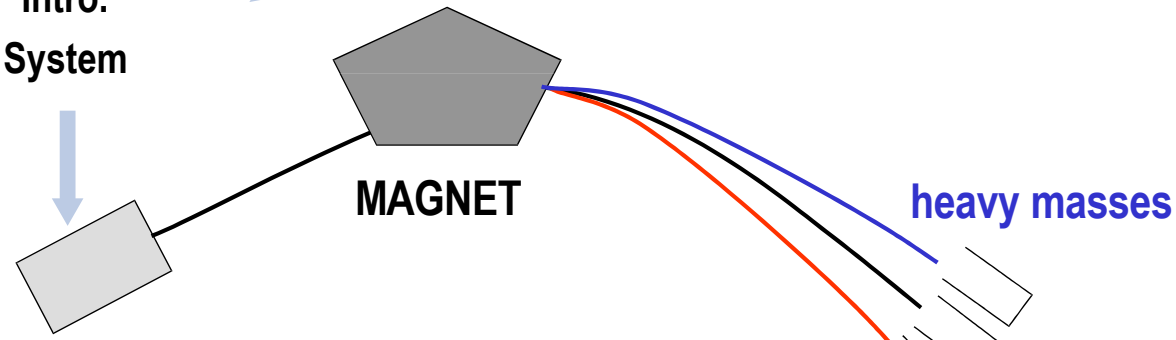
Sample Preparation

Sample

Ref. Gas

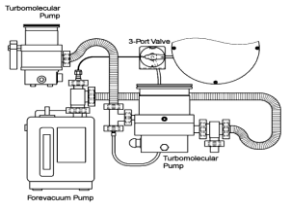
Intro. System

- Dual Inlet
- Continuous Flow



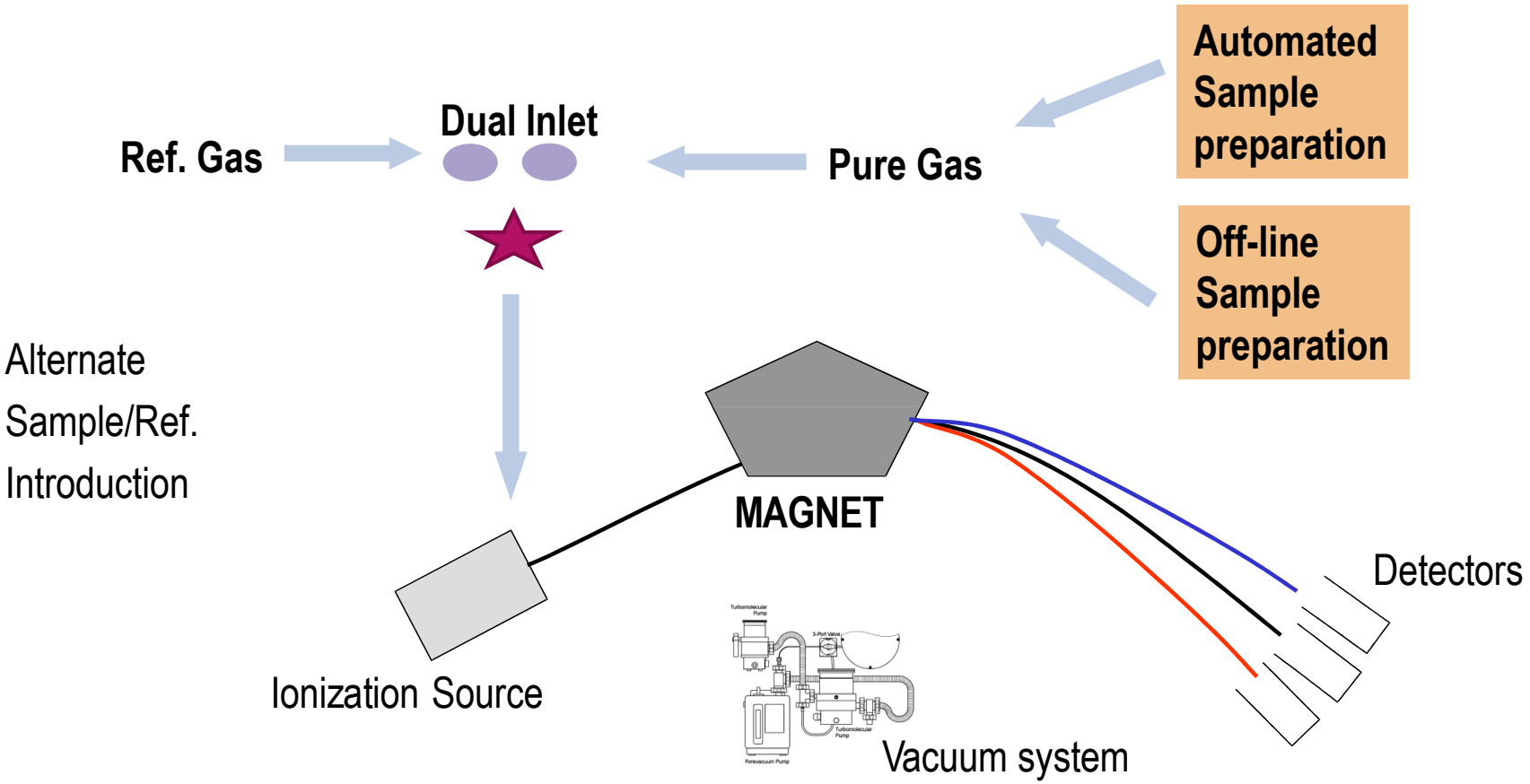
Sample/Reference Gas Comparison (ref. gas calibrated to international standard)

Ionization Source



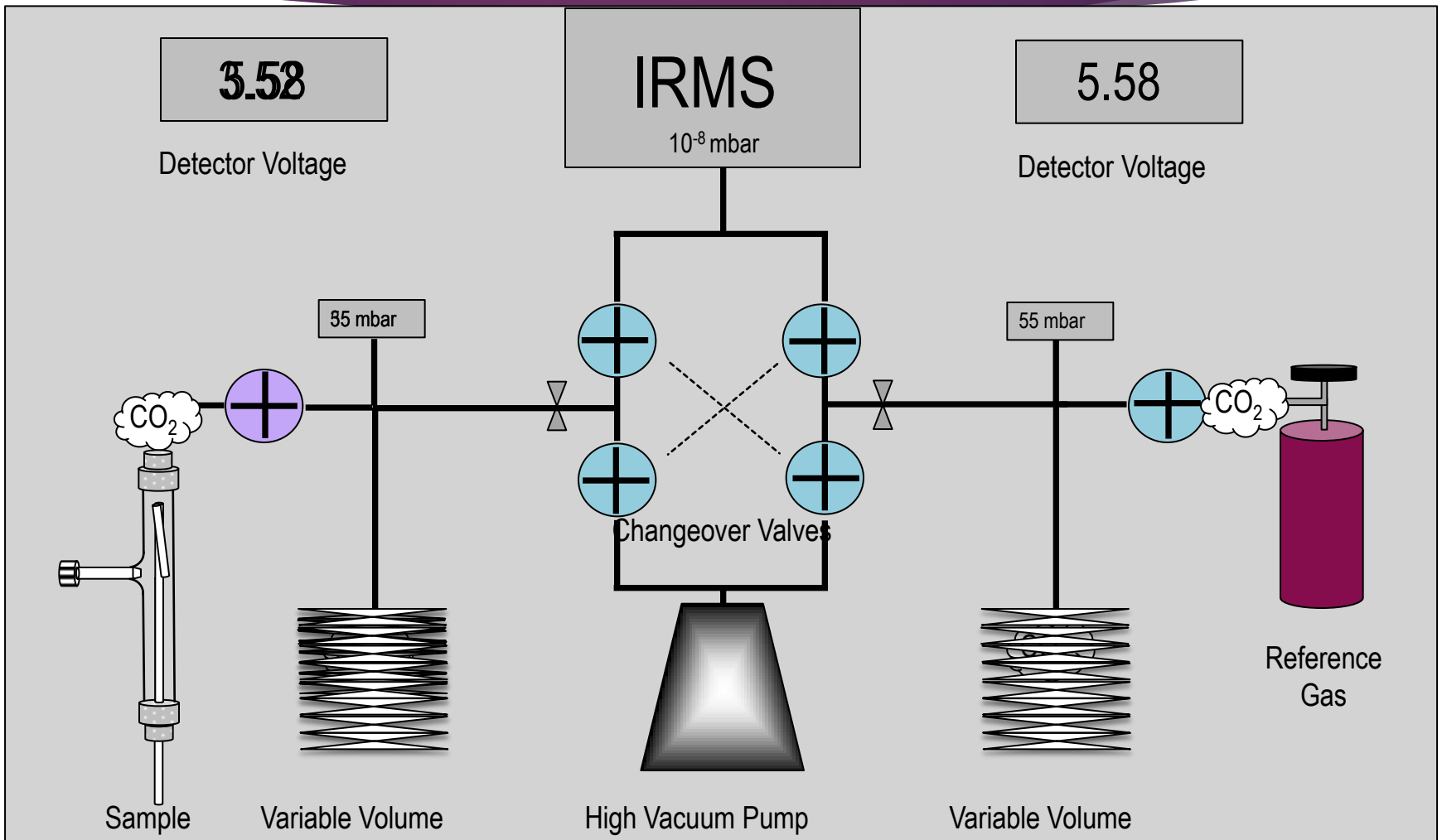
Vacuum system

Dual Inlet

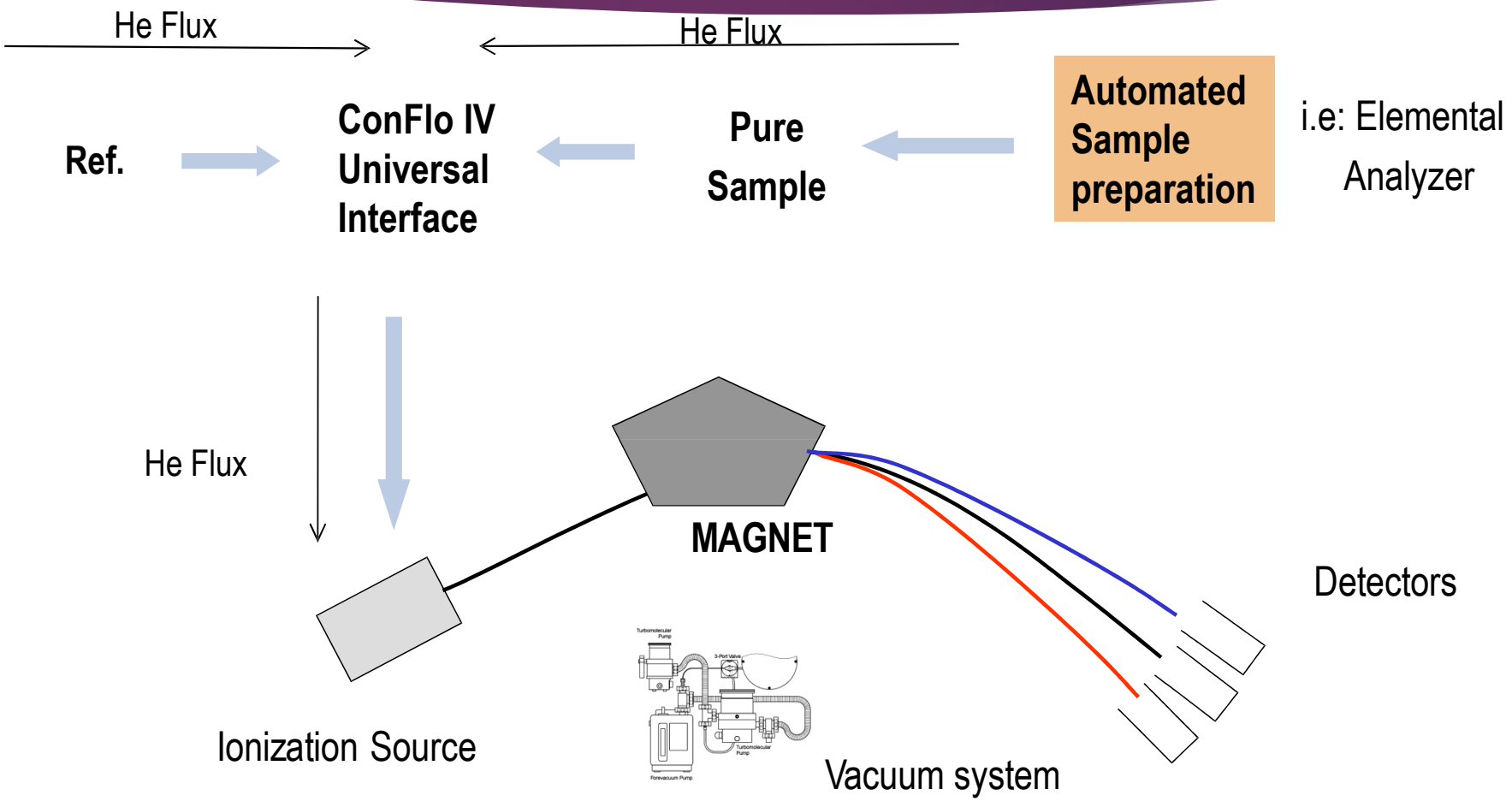


Direct comparison of a pure sample gas to a calibrated reference gas

Dual Inlet

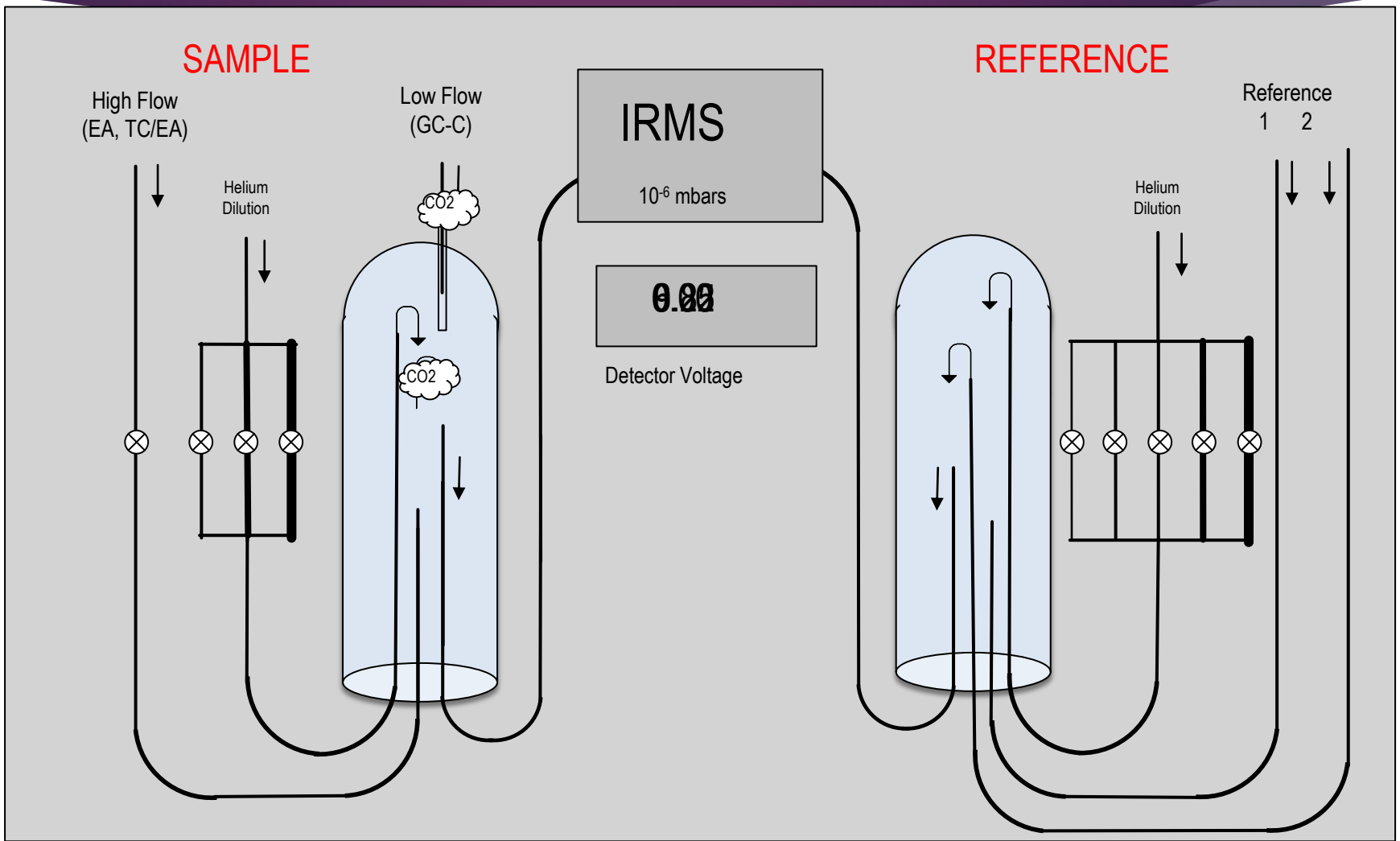

5.58
Detector Voltage
IRMS
10^{-8} mbar
5.58
Detector Voltage
55 mbar
55 mbar
CO_2
CO_2
Changeover Valves
Reference Gas
Sample
Variable Volume
High Vacuum Pump
Variable Volume

Continuous Flow



Sample as a transient signal, reference gas injected as a gas pulse

Continuous Flow



Applications

- Forensic sciences- determining whether samples of chemically similar substances such as drugs, explosives, fibres, paints, inks, tapes or adhesives may share a common source or history.
- Monitoring of atmospheric gases to distinguish between natural and anthropogenic sources.
- Climate studies.
- Water cycle research.
- Identifying the adulteration of foods with cheaper ingredients.
- Archeology / Geosciences – Establishing the extent and temperature of post-burial alteration of rocks.
- Biological sciences – photosynthetic pathways, Human and plant physiology.
- Toxicology- Distinguishing endogenous verses exogenous biochemical.

Thank You