Furth lecture

Reactor Production and Accelerator Production and Radionuclide Generators

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Reactor Production and Accelerator Production and Radionuclide Generators

Radioisotopes Production Methods

Radioactivity is the end-result from disturbing the balance between neutrons and protons in the atomic nucleus by :

1) adding a neutron to the nucleus, or
2) removing a proton from the nucleus,or
3) removing a neutron from the nucleus,or
4) adding a proton to the nucleus.

In practice, effects (1) and (2) , leading to the neutron rich radioisotopes, can be achieved through reactions available via a nuclear reactor

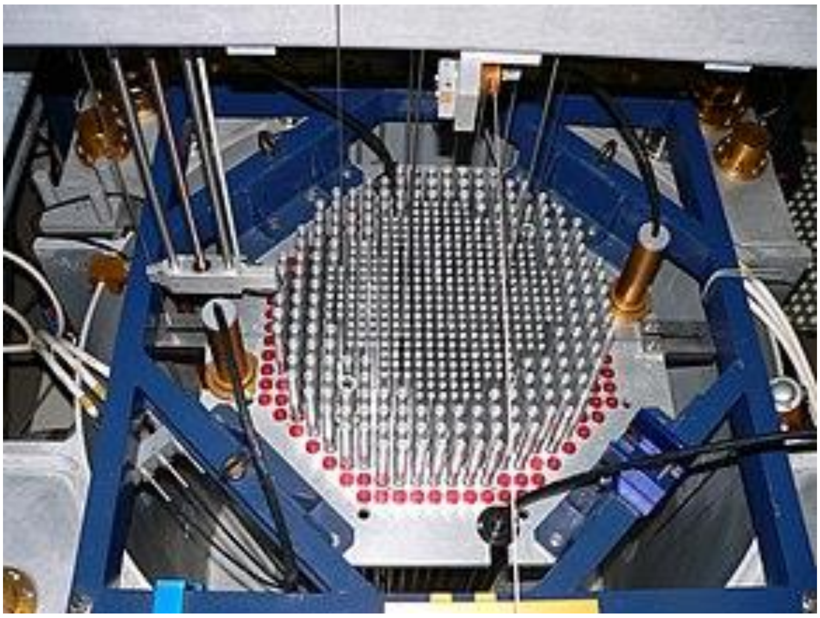
On the other hand, effects (3) and (4), leading to the neutron deficient family of radioisotopes, are achievable in a cyclotron

One clear advantage that accelerators possess is the fact that, the target and product are different chemical elements making it possible to find suitable chemical means for separation.

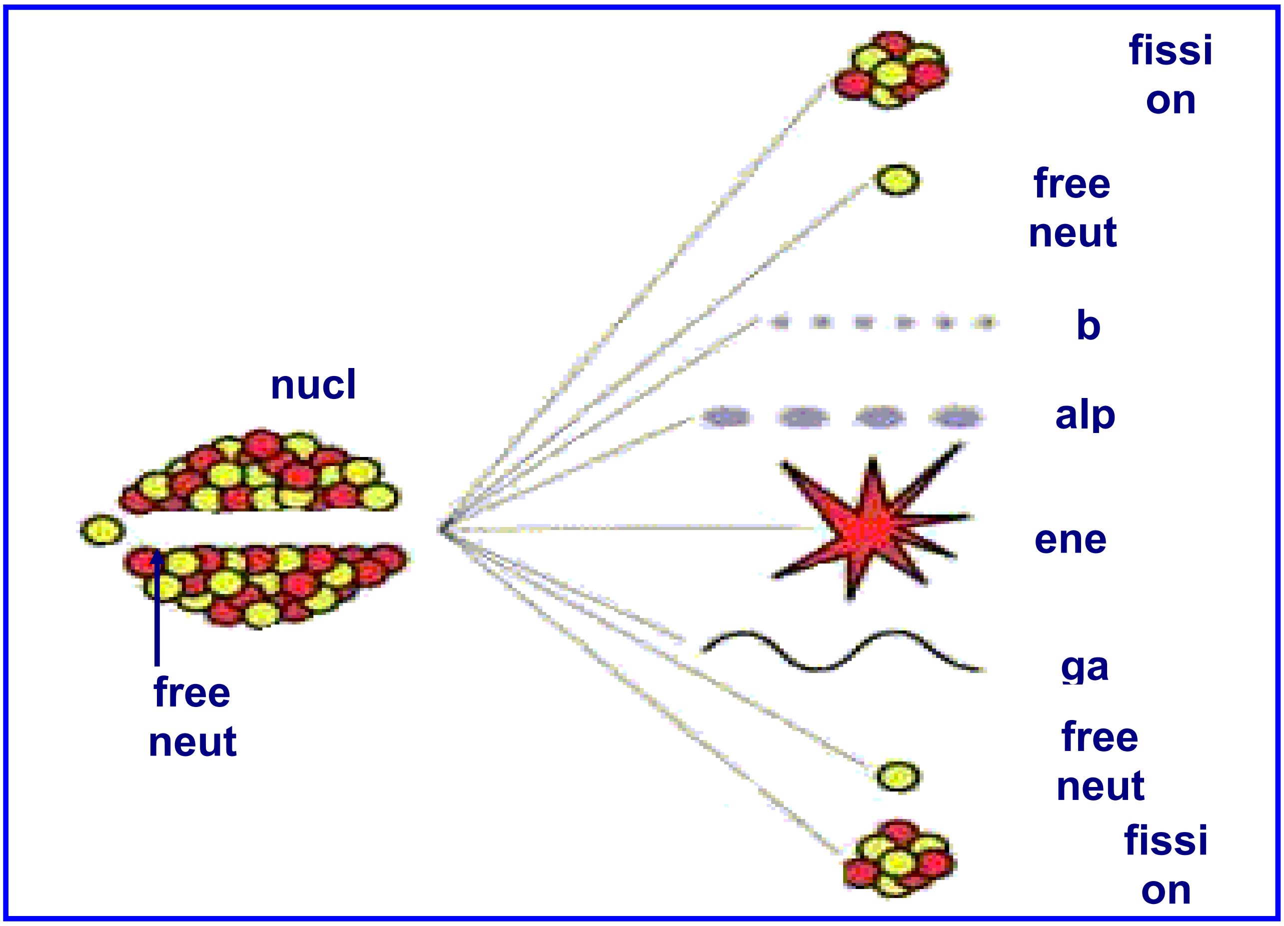
Nuclear reactor

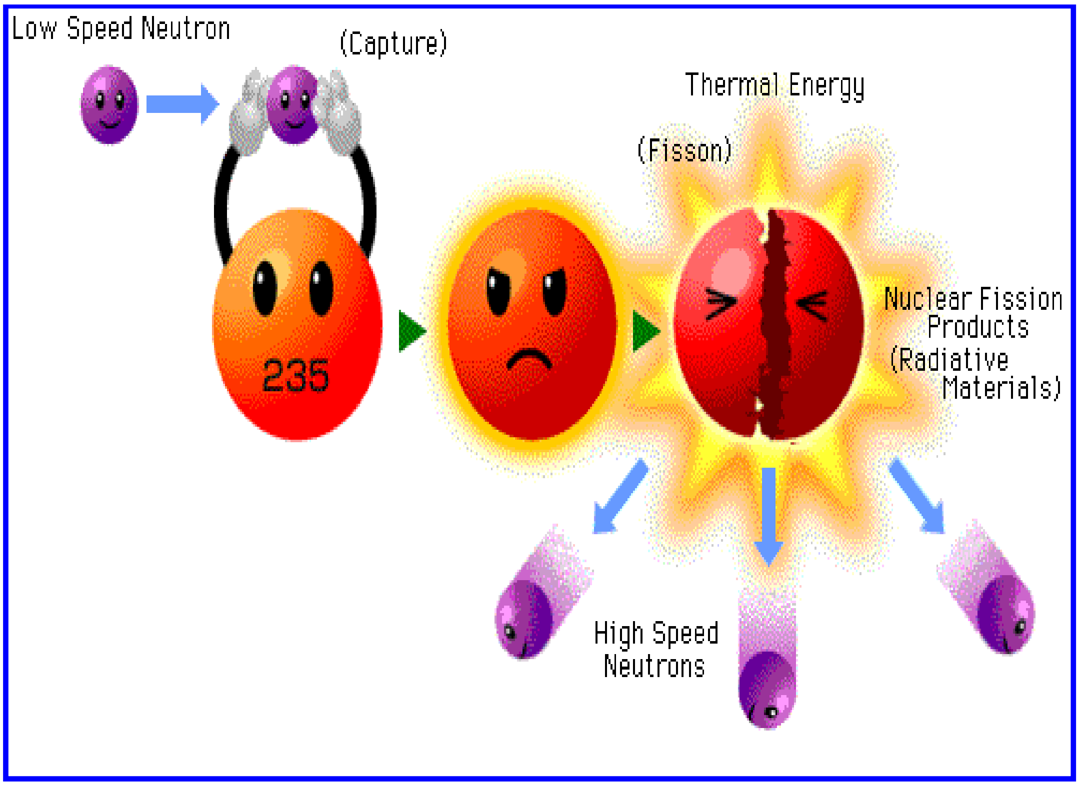
A nuclear reactor is a device used to initiate and control a fission nuclear chain reaction or nuclear fusion reactions. When a large fissile atomic nucleus such as uranium-235, Uranium-233 or plutonium-239 absorbs a neutron, it may undergo nuclear fission. The heavy nucleus splits into two or more lighter nuclei, (the fission products), releasing kinetic energy, gamma radiation, and free neutrons. A portion of these neutrons may be absorbed by other fissile atoms and trigger further fission events, which release more neutrons, and so on. This is known as a nuclear chain reaction.

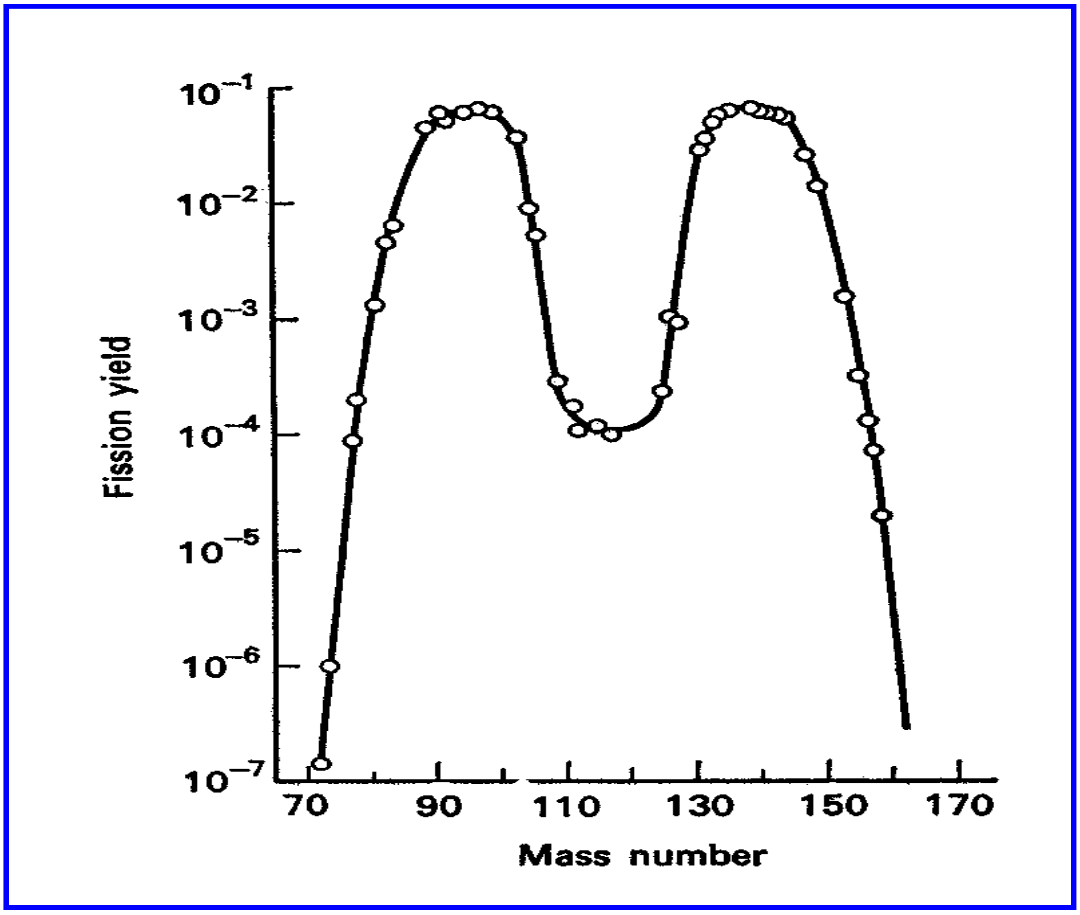
To control such a nuclear chain reaction, control rods containing neutron poisons and neutron moderators can change the portion of neutrons that will go on to cause more fission.[5] Nuclear reactors generally have automatic and manual systems to shut the fission reaction down if monitoring or instrumentation detects unsafe conditions.



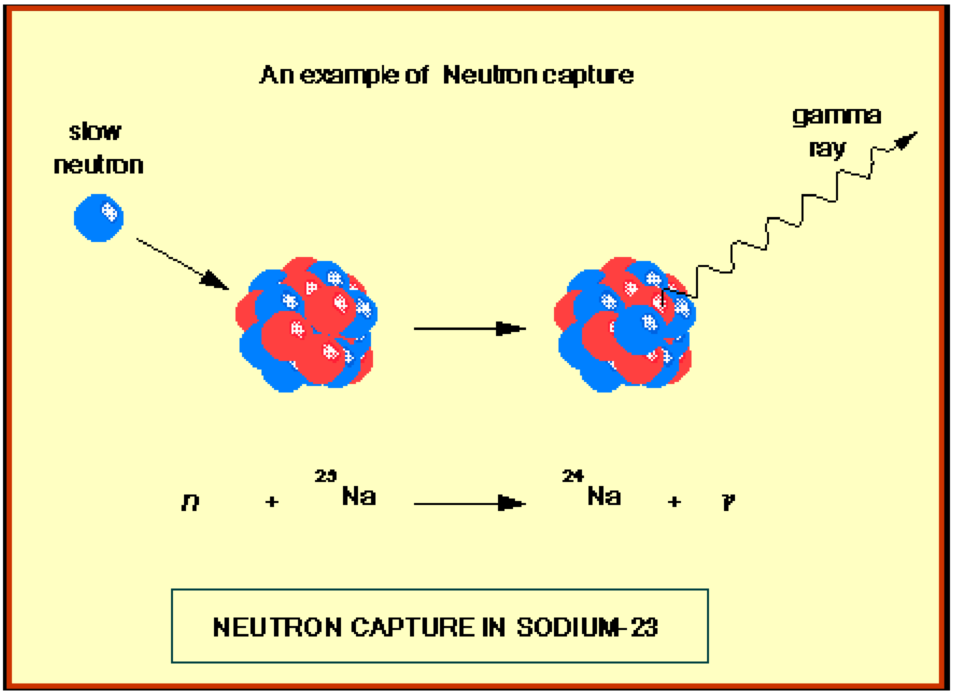
A small nuclear reactor used for research in Switzerland




Low Speed Neutron
(Capture)
Thermal Energy
(Fisson)
235
Nuclear Fission Products (Radiative Materials)
High Speed Neutrons


Fission yield
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
70
90
110
130
150
170
Mass number

Neutron Capture in ^{23}Na



$^{23}Na\ (n,\gamma)\ ^{24}Na$

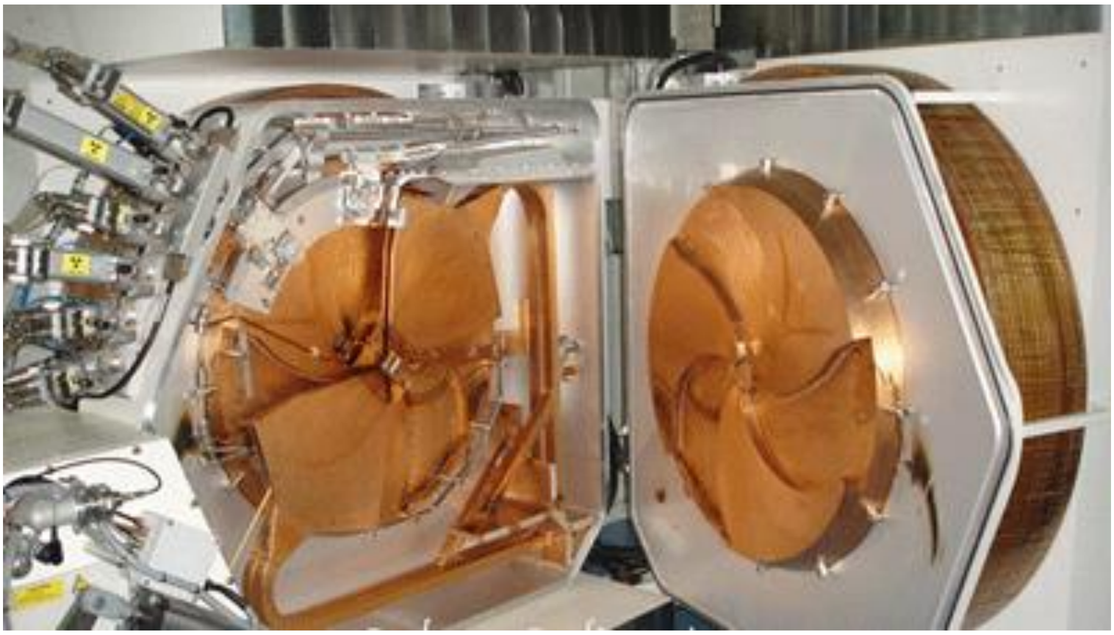
In this case, stable Na-23 (all sodium consists of this isotope, I.e. it is 100% abundant) absorbs a neutron and becomes radioactive Na-24. A gamma ray photon is emitted in this reaction.

Na-24 happens to be radioactive, with a half-life of about 15 hours.

Cyclotrons

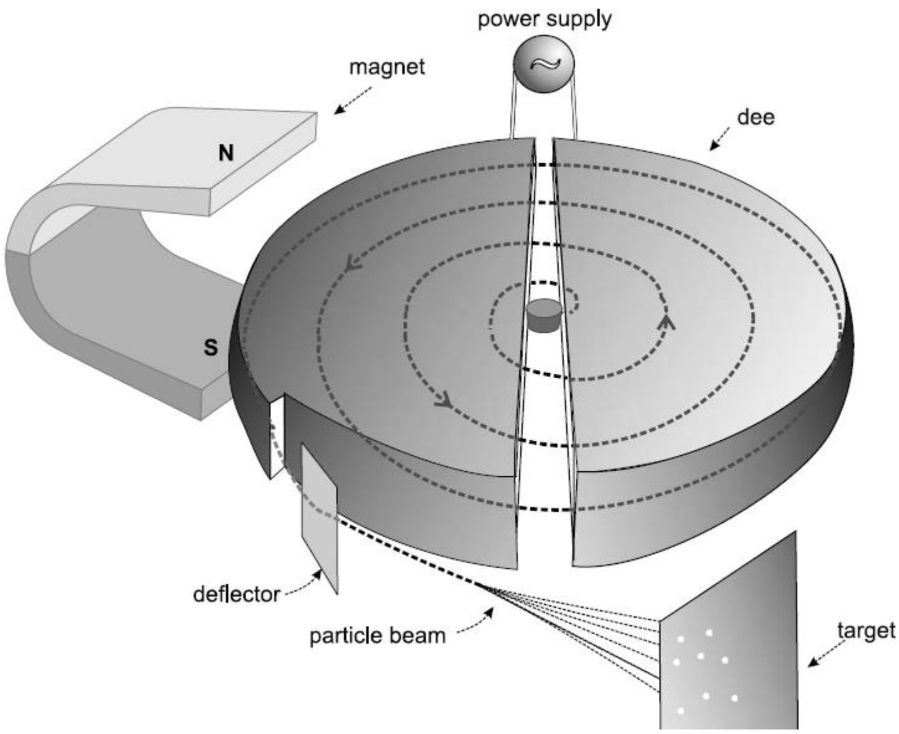
Cyclotrons are circular devices in which charged particles such as protons and alpha particles are accelerated in a spiral path within a vacuum.

The cyclotron was invented and patented by Ernest Lawrence of the University of California, Berkeley, where it was first operated in 1932.



Cyclotrons

The power supply provides a rapidly alternating voltage across the **dees** (the two halves of the circle) that accelerates the particles, which quickly acquire high kinetic energies.
They spiral outward under the influence of the magnetic field until they have sufficient velocity and are deflected into a target.
A deflector is used to direct the particles out through a window of the cyclotron into a **target**.

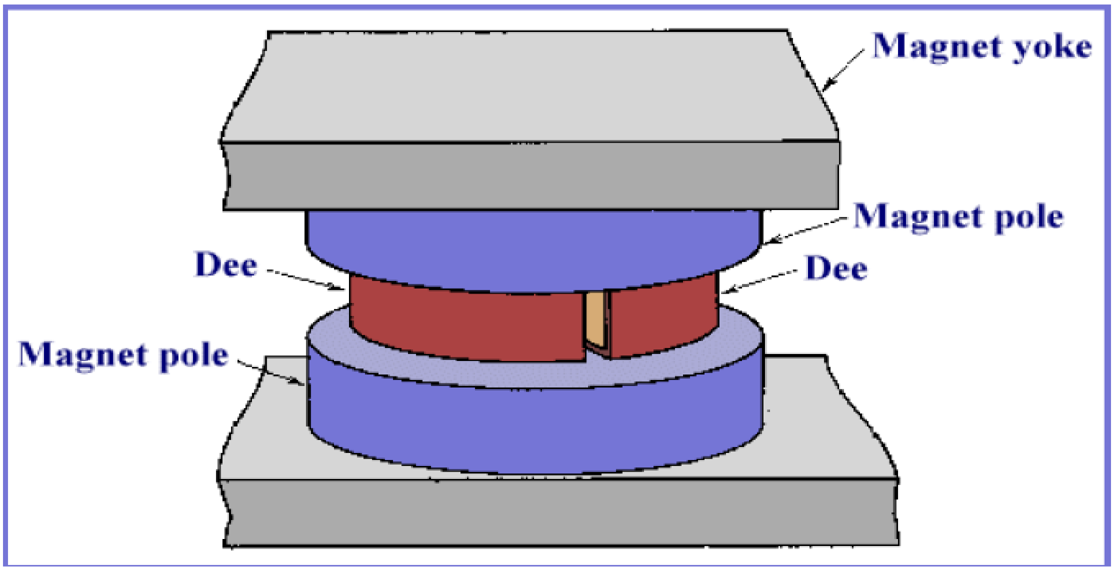


Some of the particles/Kinetic energy incorporated into the nuclei of the target atoms and make them unstable.

How to write it?

Target atom (bombarding particle, emitted particle) product nuclide

$^{18}O(p,n)^{18}F$ $^{68}Zn(p,2n)^{67}Ga$ $^{10}B(d,n)^{11}C$ $^{66}Zn(\alpha, 2n)^{68}Ge$



Cyclotron Radioisotopes

1.Thallium-201 (73 h):

Used for diagnosis of coronary artery disease and other heart conditions such as heart muscle death and for location of low-grade lymphomas.

2.Gallium-67 (78 h):

Used for tumour imaging and localization of inflammatory lesions (infections).

3.Cobalt-57 (272 d):

Used as a marker to estimate organ size and for in-vitro diagnostic kits.

4.Indium-111 (2.8 d):

Used for specialist diagnostic studies for brain studies, infection and colon transit studies.

5.Iodine-123 (13 h):

Increasingly used for diagnosis of thyroid function, it is a gamma emitter without the beta radiation of I-131.

6.Technetium-99m (6 h):

Technetium-99m, currently used in 85% of medical applications. Used in to Image the skeleton and heart muscle in particular, but also for brain, thyroid, lungs (perfusion and ventilation), liver, spleen, kidney, gall bladder, bone marrow, salivary and lacrimal glands, heart blood pool, infection and numerous specialised medical studies.

7.Krypton-81m (13 sec) from Rubidium-81 (4.6 h):

Kr-81m gas can yield functional images of pulmonary ventilation, e.g. inasthmatic patients, and for the early diagnosis of lung diseases and function.

8.Palladium-103 (17 d):

Used to make brachytherapy permanent implant seeds for early stage prostate cancer Cyclotron

Radioisotopes for PET

Carbon-11, Nitrogen-13, Oxygen-15, Fluorine-18

These are positron emitters used in PET for studying brain physiology and pathology, in particular for localizing epileptic focus, and in dementia, psychiatry and neuropharmacology studies. They also have a significant role in cardiology. F-18 in FDG has become very important in detection of cancers and the monitoring of progress in their treatment, using PET.

1.Strontium-82 (25 d):

Used as the 'parent' in a generator to produce Rb-82.

2.Rubidium-82 (65 h):

Convenient PET agent in myocardial perfusion imaging.

3.Chromium-51 (28 d):

Used to label red blood cells and quantify gastro-intestinal protein loss.

4.Cobalt-60 (10.5 mth): Formerly used for external beam radiotherapy.

5.Copper-64 (13 h): Used to study genetic diseases affecting copper metabolism, such as Wilson's and Menke's diseases

6.Phosphorus-32 (14 d):

Used in the treatment of polycythemia vera (excess red blood cells). Beta emitter

7.Potassium-42 (12 h):

Used for the determination of exchangeable potassium in coronary blood flow.

8.Rhenium-186 (3.8 d):

Used for pain relief in bone cancer. Beta emitter with weak gamma for imaging.

9.Rhenium-188 (17 h):

Used to beta irradiate coronary arteries from an angioplasty balloon.

10.Samarium-153 (47 h):

Sm-153 is very effective in relieving the pain of secondary cancers lodged in the bone, sold as Quadramet. Also very effective for prostate and breast cancer. Beta emitter.

11.Erbium-169 (9.4 d):

Use for relieving arthritis pain in synovial joints.

12.Holmium-166 (26 h):

Being developed for diagnosis and treatment of liver tumours.

13.Iodine-125 (60 d):

Used in cancer brachytherapy (prostate and brain), also diagnostically to evaluate the filtration rate of kidneys and to diagnose deep vein thrombosis in the leg. It is also widely used in radioimmuno-assays to show the presence of hormones in tiny quantities.

14.Iodine-131 (8 d):

Widely used in treating thyroid cancer and in imaging the thyroid; also in diagnosis of abnormal liver function, renal (kidney) blood flow and urinary tract obstruction. A strong gamma emitter, but used for beta therapy.

15.Iridium-192 (74 d):

Supplied in wire form for use as an internal radiotherapy source for cancer treatment (used then removed).

16.Iron-59 (46 d):

Used in studies of iron metabolism in the spleen.

17.Selenium-75 (120 d):

Used in the form of seleno-methionine to study the production of digestive enzymes.

18.Sodium-24 (15 h):

For studies of electrolytes within the body.

19.Strontium-89 (50 d):

Very effective in reducing the pain of prostate and bone cancer. Beta emitter.

20.Xenon-133 (5 d):

Used for pulmonary (lung) ventilation studies.

21.Ytterbium-169 (32 d):

Used for cerebrospinal fluid studies in the brain.

22.Yttrium-90 (64 h):

Used for cancer brachytherapy and as silicate colloid for the relieving the pain of arthritis in larger synovial joints. Pure beta emitter.

اسالة متنوعة

Q1………………used for cancer brachytherapy and as silicate colloid for the relieving the pain of arthritis in larger synovial joints. Pure beta emitter.

A. Selenium-75 B. Iron-59 C. Sodium-24 D. Strontium-89 E. Yttrium-90 Q2………………used for cerebrospinal fluid studies in the brain and (32 d)

A. Selenium-75 B. Iron-59 C. Sodium-24 D. Ytterbium-169 E. Yttrium-90

Q3………………very effective in reducing the pain of prostate and bone cancer. Beta emitter.

A. Selenium-75 B. Iron-59 C. Sodium-24 D. Strontium-89 E. Yttrium-90

Q4……….. used for pulmonary (lung) ventilation studies, and the physical half life is (5 d).

A. Cobalt-57 B.Krypton-81 C. Holmium-166 D. Indium-111 E. Xenon-133

Q5………used for studies of electrolytes within the body, and the physical half life is (15 h).

A. Selenium-75 B. Iron-59 C. Sodium-24 D. Strontium-89 E. Yttrium-90