Quick Intro to

# Materials in geant4

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Geant4 Training event – Calorimetry in HEP

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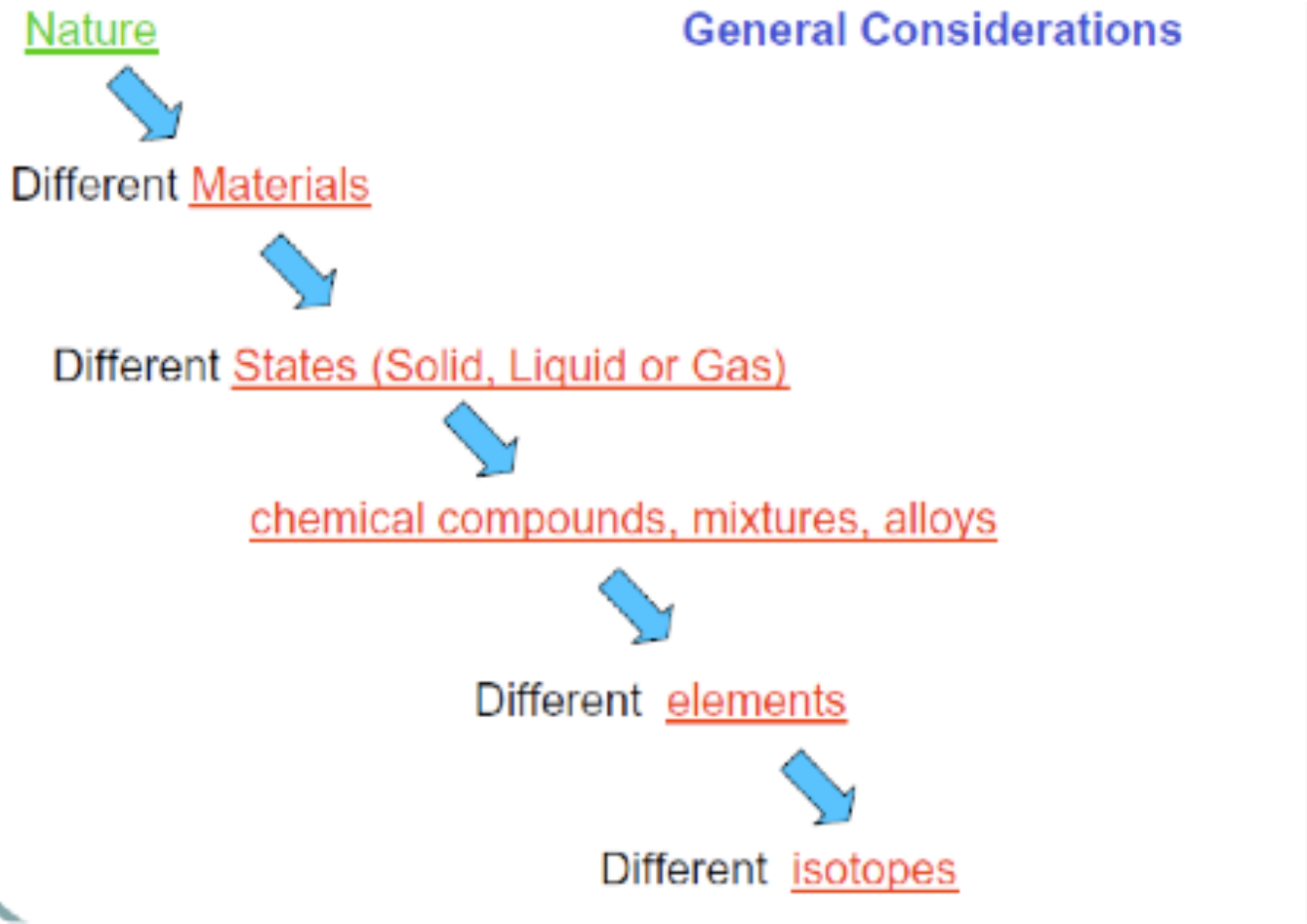
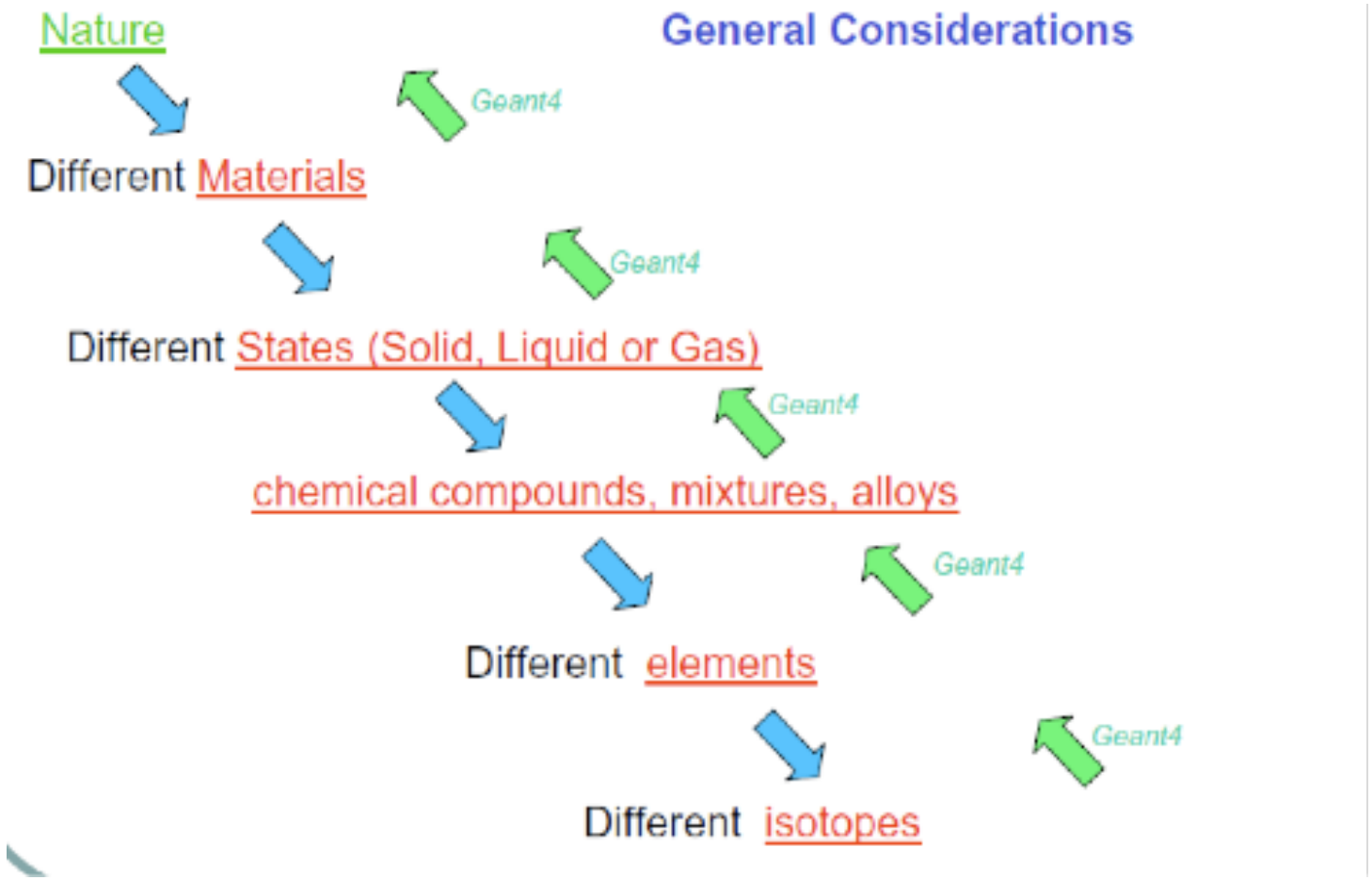
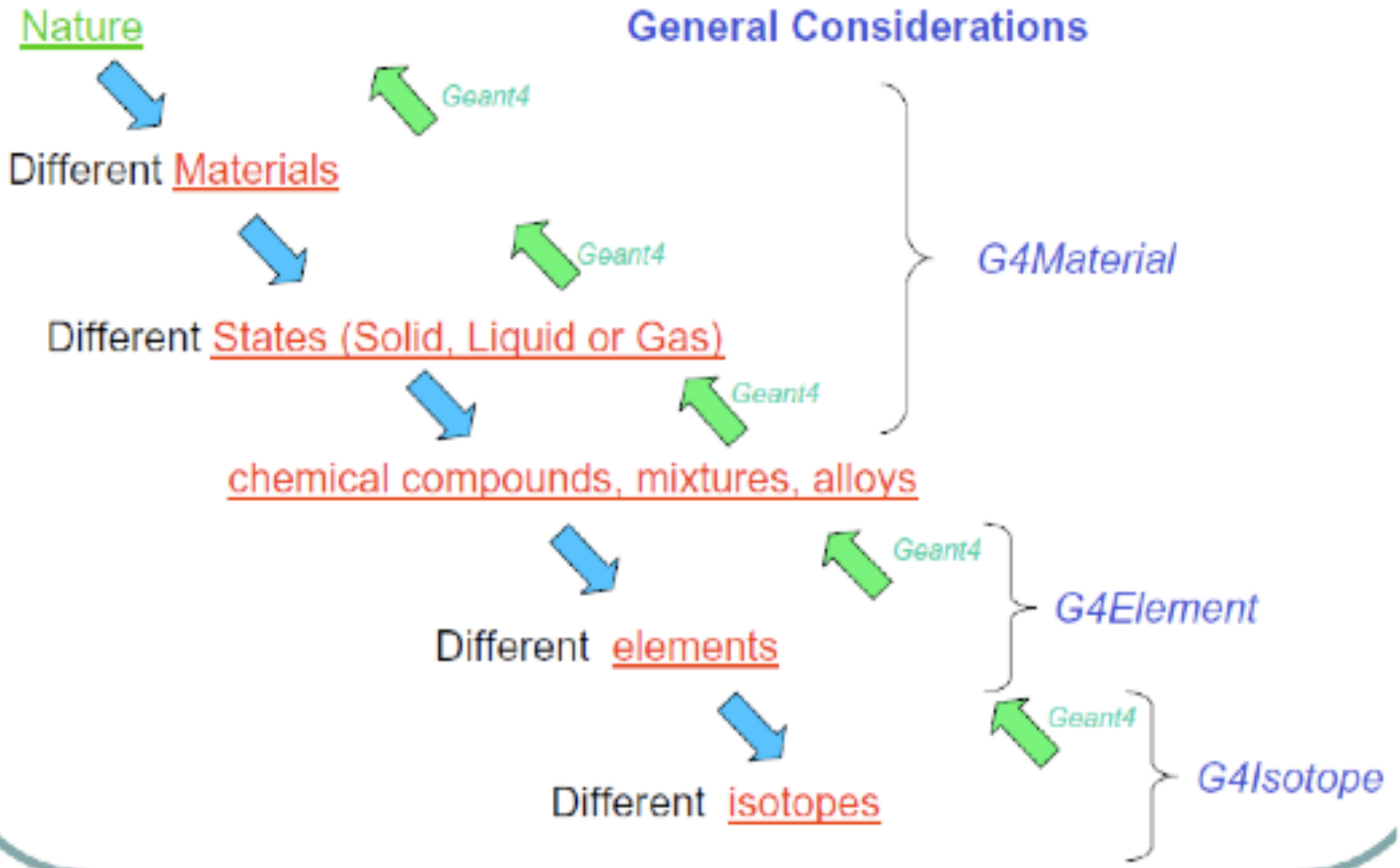
# Materials, Elements and isotopes



# Materials, Elements and isotopes



## General Considerations



The *G4Element* and *G4Isotope* class describes the properties of the atoms:

- atomic number,
- number of nucleons,
- atomic mass,
- as well as quantities such as cross sections per atom, etc.

The *G4Material* class describes the macroscopic properties of matter:

- density,
- state,
- temperature,
- pressure,
- as well as macroscopic quantities like radiation length, mean free path, dE/dx, etc.

(A) One way of defining an Isotope } G4Isotope.hh

(B) Twos ways of defining an Element
How to use AddIsotope(…) with abundance } G4Element.hh

(C) Three ways of defining a Material
How to use AddElement(…) with natomes
How to use AddMaterial(…) with fractionmass } G4Material.hh

# Isotopes.

## Public Member Function

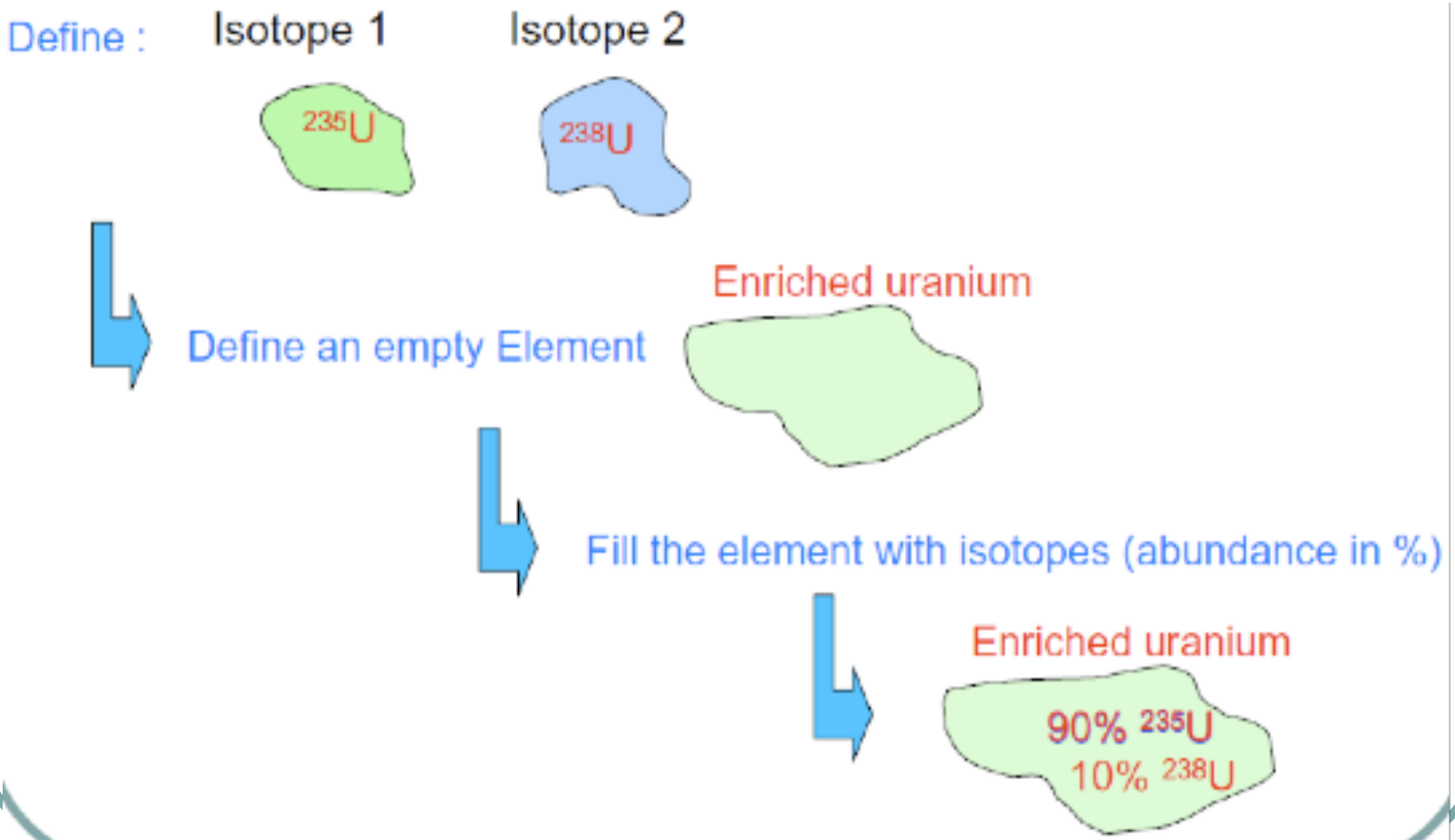
*Only one way of defining an Isotope*

G4Isotope (const G4string &name, G4int Z, G4int n,G4double A.)


***Small example 1:***

```
G4string symbol;
G4double Z, A;
G4Isotope* iso_U8  = new G4Isotope("U238"  ,symbol="O" , z= 8, n=238, a= 238.03*g/mole);
```

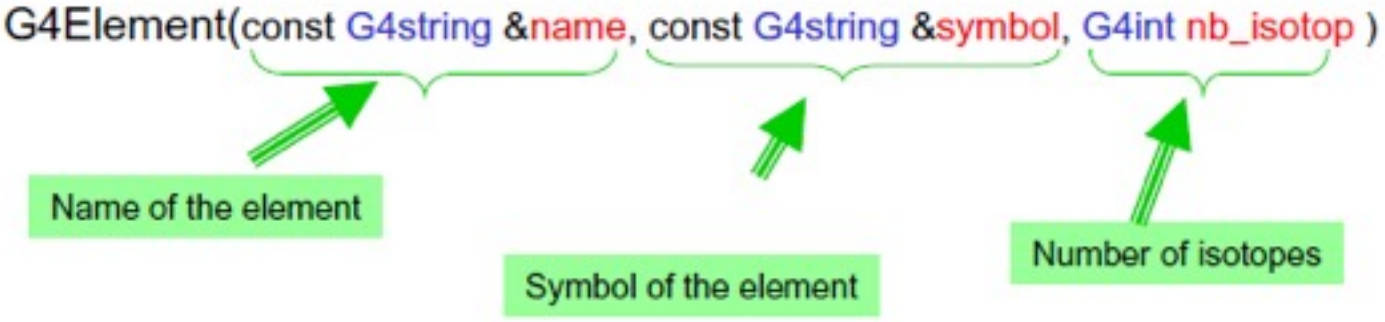
# Elements with isotopes (example)



# Elements.

## Public Member Function

*First way of defining an element using isotopes*




***Small example 3:***

```
G4string symbol;
G4int ncomponents;
G4Element* U  = new G4Element("enriched Uranium",symbol="U",ncomponents=2);
```

# Elements with isotopes (example)

***Step 1:***

```
G4string symbol; G4int z, n; G4double a;
G4Isotope* iso_U8 = new G4Isotope("U238" ,symbol="O" , z= 92, n=238, a= 238.03*g/
mole);
G4Isotope* iso_U5 = new G4Isotope("U238" ,symbol="O" , z= 92, n=235, a= 235.01*g/
mole);
```

***Step 2:***

```
G4int ncomponents;
        G4Element* el_U = new
        G4Element("enrichedUranium",symbol="U",ncomponents=2);
```

***Step 3:***

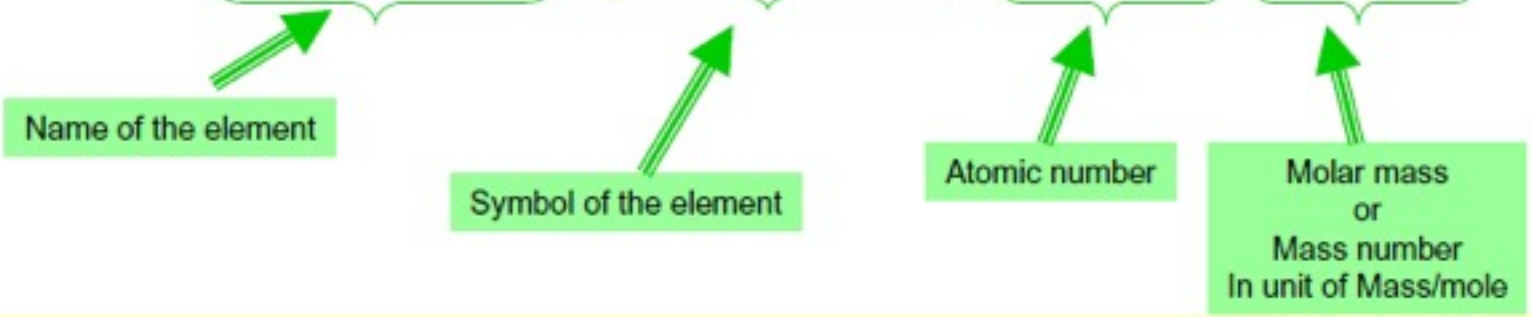
```
                el_U->AddIsotope(U5, abundance=
                90.*perCent);
el_U->AddIsotope(U8, abundance= 10.*perCent);
```

# Elements. (simple way)

**Public Member Function**

*simple way of defining an element*

G4Element(const G4string &name, const G4string &symbol, G4double Zeff, G4double Aeff )




***Small example 2:***

```
G4string symbol;
G4double Z, A;
G4Element* el_O  = new G4Element("Oxygen"  ,symbol="O" , z= 8., a= 16.00*g/mole);
```

# Materials. (simple way)

## Public Member Function

*simple way of defining a Material using simple elements*

```
G4Material(  const G4string &name,
             const G4string &symbol,
             G4double z,
             G4double a,
             G4double density,
             G4State the_State,
             G4double STP_temperature,
             G4double STP_pressure
             )
```

- Name of the material
- Symbol of the material
- Atomic number
- Atomic mass
- Density of the material
- Material state: *kStateGas, kStateSolid, kStateLiquid*
- Material temperature STP
- Material pressure STP

# Materials. (Mixture)

**Public Member Function**

*One way of defining a Material using mixture*

```
G4Material( const G4string &name,
            const G4string &symbol,
            G4int nb_components,
            G4State the_State,
            G4double STP_temperature,
            G4double STP_pressure
            )
```

- `name` → Name of the material
- `symbol` → Symbol of the material
- `nb_components` → Number of components
- `the_State` → Material state: *kStateGas, kStateSolid, kStateLiquid*
- `STP_temperature` → Material temperature STP
- `STP_pressure` → Material pressure STP

# Example Materials. (simple way)

Directly using the information of an element !!

```
G4double z, a, density,T,P;

G4Material* mat_Al =  new G4Material(  "Aluminium",
                                       z=13.,
                                       a=26.98*g/mole,
                                       density=2.700*g/cm3
                                       kStateSolid,
                                       T=273.*kelvin,
                                       P=1.*atmosphere);
```

OR simply

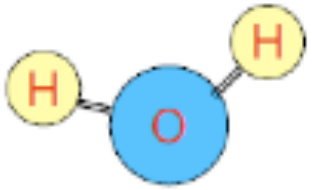
```
G4double z, a, density;

G4Material* mat_Al =  new G4Material(  "Aluminium",
                                       z=13.,
                                       a=26.98*g/mole,
                                       density=2.700*g/cm3 );
```

# Example Materials. (diff elements)

Example of water molecule

```
G4double z,a,density;
G4int ncomponents;
G4string symbol;
```




```
G4Element* el_H  = new G4Element("Hydrogen",symbol="H" , z= 1., a= 1.01*g/mole);
G4Element* el_O  = new G4Element("Oxygen"  ,symbol="O" , z= 8., a= 16.00*g/mole);
```

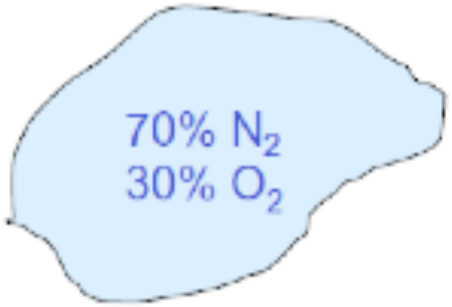
```
G4Material* mat_H2O = new G4Material("Water", density= 1.000*g/cm3, ncomponents=2);

mat_H2O->AddElement(el_H, natoms=2);

mat_H2O->AddElement(el_O, natoms=1);
```

# Example Materials. (Mixture)

Example of Air (simple one)




```
G4double z,a,density;
G4int ncomponents;
G4string symbol;
```

```
G4Element* el_N  = new G4Element("Hydrogen",symbol="N" , z= 1., a= 1.01*g/mole);
G4Element* el_O  = new G4Element("Oxygen"  ,symbol="O" , z= 8., a= 16.00*g/mole);
```

```
G4Material* mat_Air =  new G4Material("Air"  , density= 1.290*mg/cm3, ncomponents=2);
mat_Air->AddElement(el_N, fractionmass=0.7);
mat_Air->AddElement(el_O, fractionmass=0.3);
```

# Example Materials. (Mixture of elements and materials)

Example of Aerogel (62.5 % $SiO_2$, 37.4% $H_2O$, 0.1% C)

```
G4double z,a,density;
G4int ncomponents;
G4string symbol;
```

```
G4Element* el_N  = new G4Element (..... etc
G4Element* el_O  = new G4Element (.....etc
..... etc same for el_Si and el_C
```

```
G4Material* mat_SiO2  = new G4Material (..... etc

G4Element* mat_H2O  = new G4Material (.....etc
```

```
G4Material* mat_Aerog =
new G4Material("Aerogel", density= 0.200*g/cm3, ncomponents=3);
Aerog->AddMaterial(mat_SiO2, fractionmass=62.5*perCent);
Aerog->AddMaterial(mat_H2O , fractionmass=37.4*perCent);
Aerog->AddElement (el_C    , fractionmass= 0.1*perCent);
```

# Elements and Materials *most elegante way !!*

Using the NIST Grant4 Database

```
#include "G4Material.hh"
#include "G4NistManager.hh"
```

```
G4NistManager* man = G4NistManager::Instance();
```

```
// define pure NIST materials //
G4Material* Al = man->FindOrBuildMaterial("G4_Al");
G4Material* Cu = man->FindOrBuildMaterial("G4_Cu");
```

```
// define NIST materials //
G4Material* H2O = man->FindOrBuildMaterial("G4_WATER");
G4Material* SiO2 = man->FindOrBuildMaterial("G4_SILICON_DIOXIDE");
G4Material* Air = man->FindOrBuildMaterial("G4_AIR");
```

# Summary Materials, Elements and Isotopes

For elements with isotopes

***In Last Step :***

```
el_U->AddIsotope(U5, abundance= 90.*perCent);
el_U->AddIsotope(U8, abundance= 10.*perCent);
```

For Materials (mixtures)

***In Last Step :***

```
mat_Material->AddElement(Element, natomes= ---);

Or

mat_Material->AddElement(Element, fractionmass= ---);

Or

mat_Material->AddMaterial(subMaterial, fractionmass= ---);
```

# Summary Materials, Elements and Isotopes

## Using the NIST Grant4 Database

```
#include "G4NistManager.hh"
```

```
G4NistManager* man = G4NistManager::Instance();
```

```
……. man->FindOrBuildMaterial("G4_WATER");
```

# Training