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# Materials

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# Materials

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- In nature, general materials (compounds, mixtures) are made by elements and elements are made by isotopes. These are the three main classes designed in Geant4
  - The G4Element class describes the properties of the atoms: atomic number, number of nucleons, atomic mass, shell energy...
  - The G4Isotope class permits to describe the isotopic composition of a material
  - The G4Material class describes the macroscopic properties of the matter: density, state, temperature, pressure, radiation length, mean free path,  $dE/dx$ ...
  - G4Material is the class visible to the rest of the toolkit and it is used by the tracking, the geometry and physics
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# Define a simple material

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- A simple material can be created by specifying its name, density, mass of a mole and atomic number:

```
#include "G4Material.hh"  
...  
G4double density=1.390*g/cm3;  
G4double a=39.95*g/mole;  
G4double z=18.;  
G4String name;  
...  
G4Material* LAr = new G4Material(name="Liquid Argon", z, a, density);
```

- The pointer to the material will then be used to specify the material a given logical volume is made of
-

# Define a molecule

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- A molecule is built from its components, by specifying the number of atoms in the molecule.

```
#include "G4Element.hh"
#include "G4Material.hh"
...
G4double a=1.01*g/mole;
G4double z;
G4String name,symbol;
G4Element* H = new G4Element(name="Hydrogen", symbol="H", z=1.,a);

a=16.0*g/mole;
G4Element* O = new G4Element(name="Oxygen", symbol="O", z=8.,a);

G4double density=1.000*g/cm3;
G4int ncomponent,natoms;
G4Material* H2O = new G4Material(name="Water",density,ncomponents=2);
H2O->AddElement(H,natoms=2);
H2O->AddElement(O,natoms=1);
```

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# Define a mixture (by fractional mass)

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- Air is built from Nitrogen and Oxygen by giving the fractional mass of each component

```
#include "G4Element.hh"
#include "G4Material.hh"
...
G4double a=14.01*g/mole;
G4double z;
G4String name,symbol;
G4Element* N = new G4Element(name="Nitrogen", symbol="N",z=7.,a);

a=16.0*g/mole;
G4Element* O = new G4Element(name="Oxygen", symbol="O",z=8.,a);

G4double fractionmass,density=1.290*mg/cm3;
G4int ncomponent,natoms;
G4Material* Air = new G4Material(name="Air",density,ncomponents=2);
Air->AddElement(N,fractionmass=70*percent);
Air->AddElement(O,fractionmass=30*percent);
```

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# Materials as mixtures of materials

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- ArCO2 can be defined as mixture of an element and a

material:

```
#include "G4Element.hh"
```

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

```
...
```

```
G4double a,z,fractionmass,density;
```

```
G4String name,symbol;
```

```
G4int ncomponents,natoms;
```

```
G4Element* Ar = new G4Element(name="Argon", symbol="Ar", z=18., a=39.95*g/mole);
```

```
G4Element* C = new G4Element(name="Carbon", symbol="C", z=6., a=12.00*g/mole);
```

```
G4Element* O = new G4Element(name="Oxygen", symbol="O", z=8., a=16.00*g/mole);
```

```
G4Material* CO2 = new G4Material(name="CO2", density=1.977*mg/cm3, ncomponents=2);
```

```
CO2->AddElement(C,natoms=1);
```

```
CO2->AddElement(O,natoms=2);
```

```
G4Material* ArCO2=new G4Material(name="ArCO2", density=1.8*mg/cm3, ncomponents=2);
```

```
ArCO2-> AddElement(Ar,fractionmass=93*percent);
```

```
ArCO2-> AddMaterial(CO2,fractionmass=7*percent);
```

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# Materials in non STP conditions

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```
#include "G4Element.hh"
#include "G4Material.hh"
...
G4double a,z,fractionmass,density;
G4String name,symbol, ncomponent,natoms;
G4Element* Ar = new G4Element(name="Argon", symbol="Ar", z=18.,a=39.95*g/mole);
G4Element* C = new G4Element(name="Carbon", symbol="C", z=6., a=12.00*g/mole);
G4Element* O = new G4Element(name="Oxygen", symbol="O", z=8.,a=16.00*g/mole);

G4double temperature=300.*kelvin;
G4double pressure=2.*atmosphere;
G4Material* CO2 = new G4Material(name="CO2",density=1.977*mg/cm3,ncomponents=2
                                kStateGas,temperature,pressure);
CO2->AddElement(C,natoms=1);
CO2->AddElement(O,natoms=2);

G4Material* ArCO2=new G4Material(name="ArCO2",density=1.8*mg/cm3,ncomponents=2
                                kStateGas,temperature,pressure);
ArCO2-> AddElement(Ar,fractionmass=93*percent);
ArCO2-> AddMaterial(CO2,fractionmass=7*percent);
```

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# Printing materials and elements

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- Materials and elements (and the tables maintained internally by Geant4) can be printed very easily with:

```
#include "G4Element.hh"  
#include "G4Material.hh"  
...  
cout<<ArCO2;  
cout<<*(G4Element::GetElementTable());  
cout<<*(G4Material::GetMaterialTable());
```