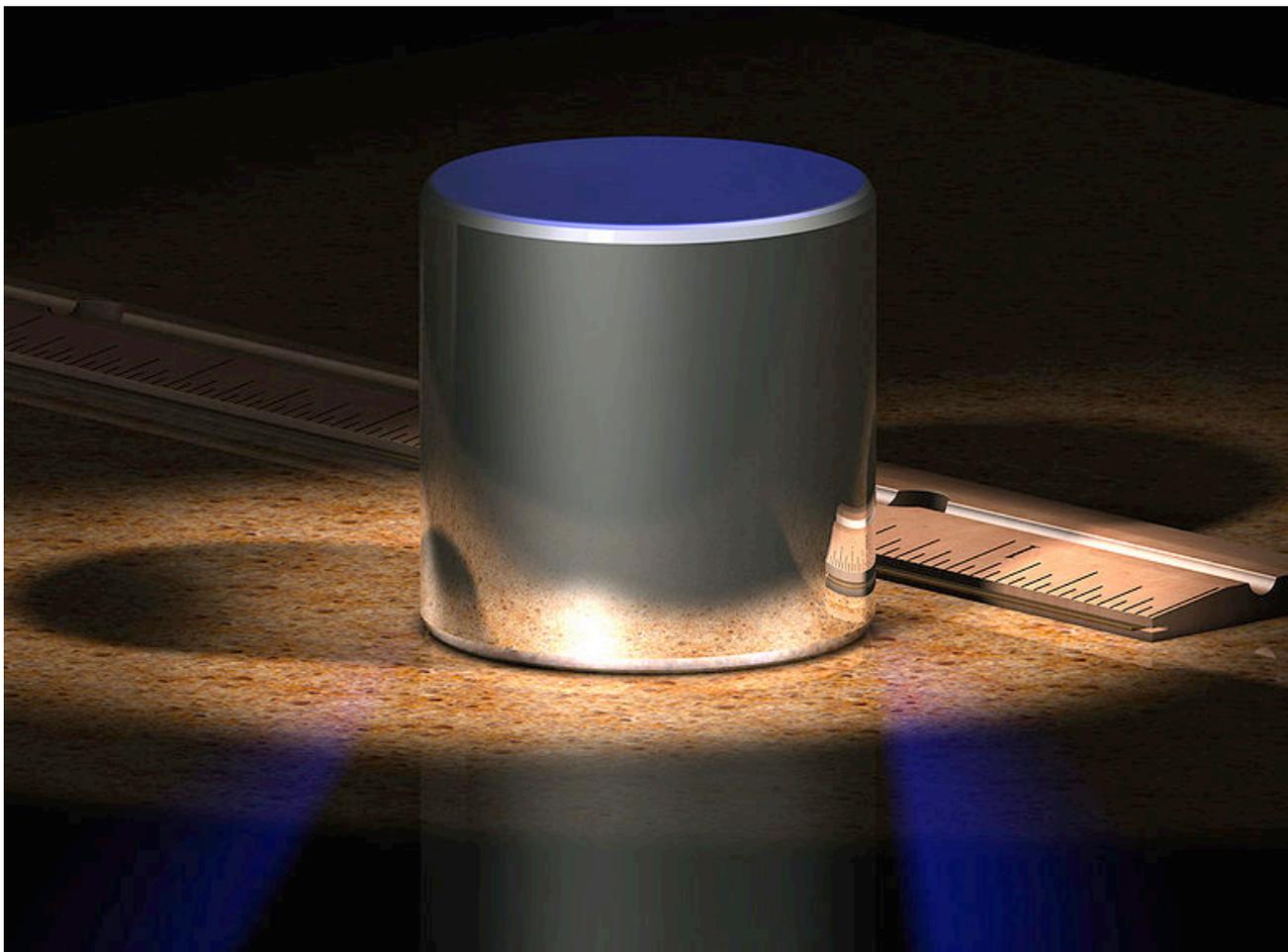
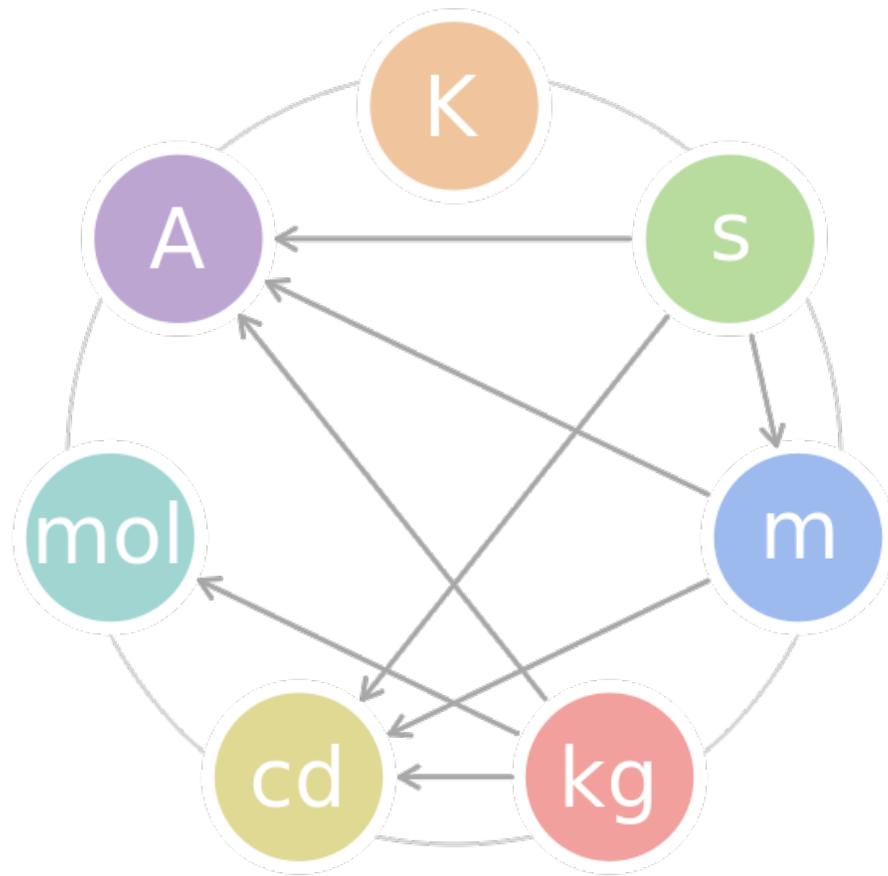


# What is a kilogram?



R. Corn  
Chem M3LC

# The kilogram is a base SI unit.



SI: International System of Units  
(from French: Le Système  
international d'unités)

The kilogram is the  
SI unit of mass.

The seven SI base units and the interdependency of their definitions. Clockwise from top: kelvin (temperature), second (time), meter (length), kilogram (mass), candela (luminous intensity), mole (amount of substance) and ampere (electric current).

# The **Second** is the SI unit of time.

*The second is defined by taking the fixed numerical value of the cesium frequency  $\Delta\nu_{Cs}$ , the unperturbed ground-state hyperfine transition frequency of the cesium-133 atom to be exactly 9,192,631,770 when expressed in the units of Hz, which is equal to  $s^{-1}$ .*

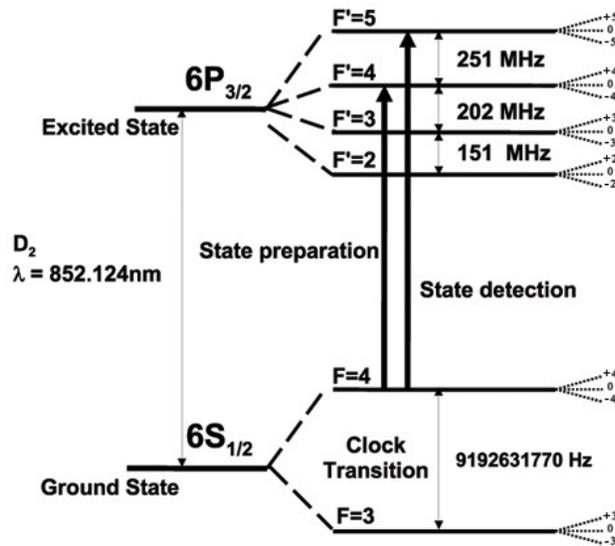


Fig. 5 – Diagram of the internal levels and transitions relevant to the Cs atomic beam clock.

*It's definition is based on a measurement that can be made anywhere.*

## Atomic Clocks!

The **Meter** is the SI unit of length.

From 1889 to 1960, the meter was defined by a Pt-Ir bar in France.



From Wikipedia.

The **Meter** is the SI unit of length.

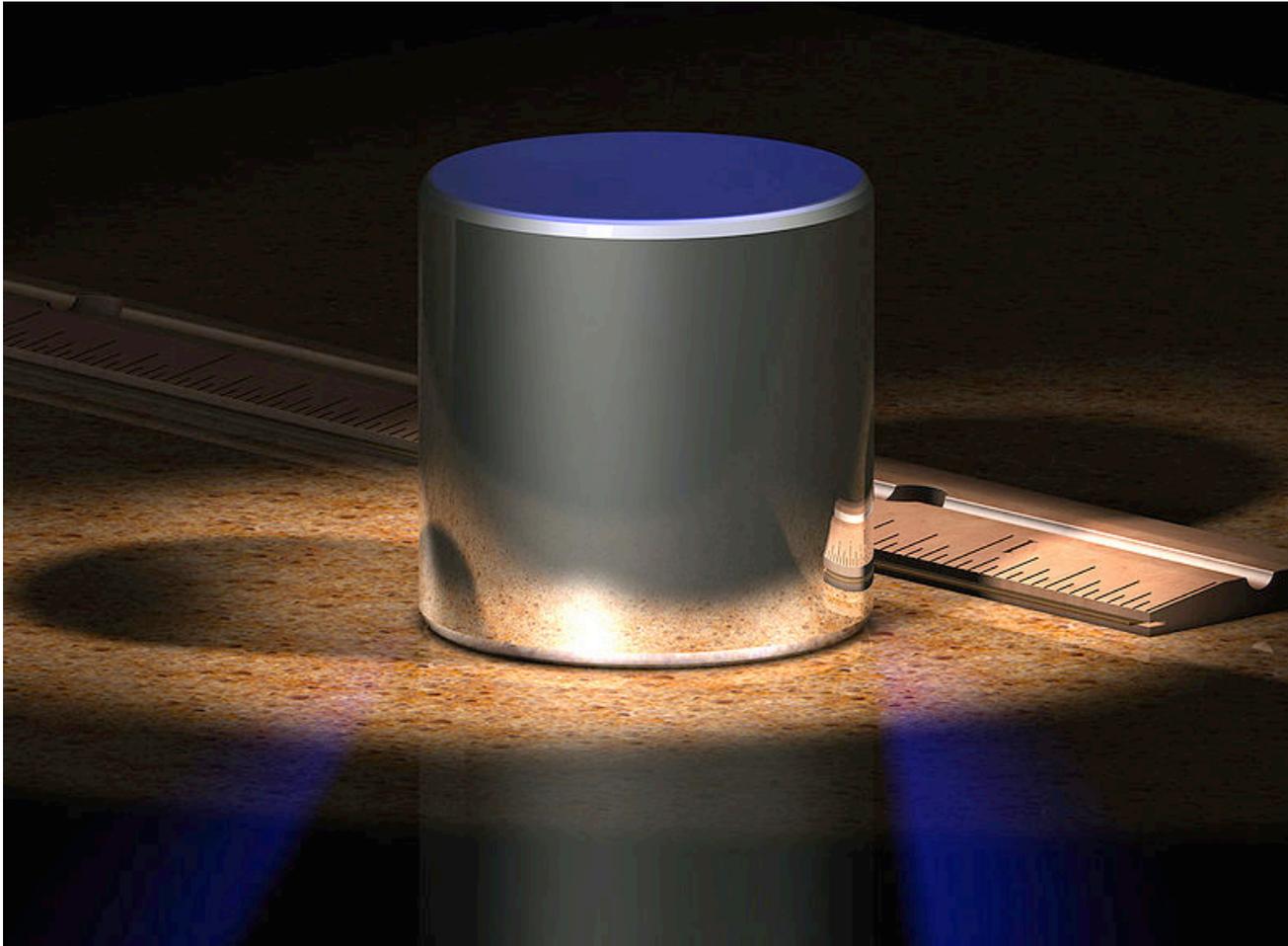
*The meter is now defined as the length of the path travelled by light in vacuum during a time interval of  $1/299,792,458$  of a second.*

*It's definition is based on a measurement that can be made anywhere.*

This definition fixes the speed of light in vacuum (c) at exactly 299,792,458 meters per second.

The **Kilogram** is the SI unit of mass.

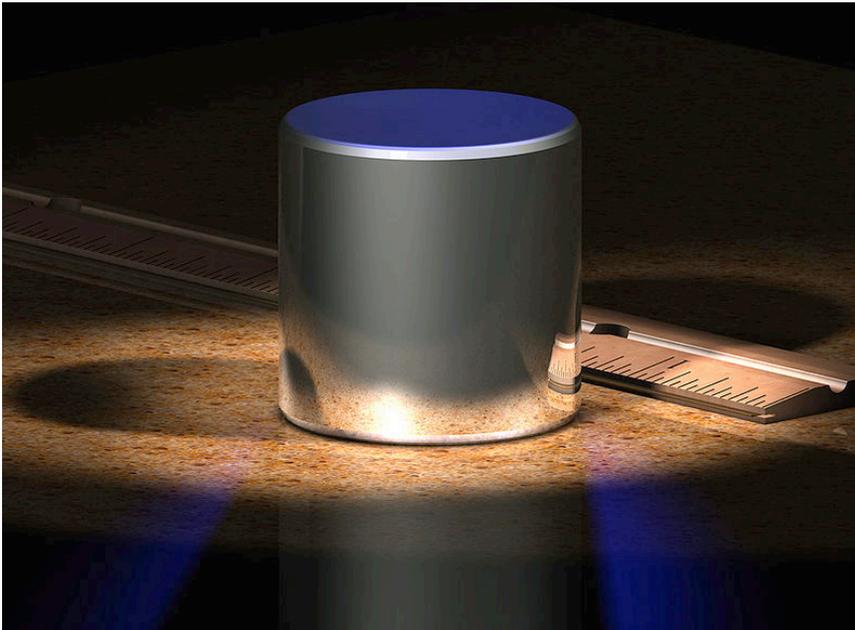
The kilogram was originally defined in 1795 as the mass one liter of water at 4°C.



From Wikipedia.

The **Kilogram** is the SI unit of mass.

*The Kilogram up to 2019 was defined as the mass of the "International Prototype Kilogram," a set of 50 platinum-iridium (90%-10%) alloy cylinders manufactured in 1875 and kept in various locations including the BIPM at Sèvres, France, near Paris.*



BIPM: International Bureau of Weights and Measures  
(Bureau international des poids et mesures)

From Wikipedia.

# Unfortunately, the French **Kilogram** is losing weight!

The New York Times

Europe

WORLD U.S. N.Y. / REGION BUSINESS TECHNOLOGY SCIENCE HEALTH SPORTS OPINION

AFRICA AMERICAS ASIA PACIFIC EUROPE MIDDLE EAST

SÈVRES JOURNAL

## Missing Micrograms Set a Standard on Edge

By SARAH LYALL

Published: February 12, 2011

SÈVRES, France — No one knows exactly why the international prototype of the kilogram, as pampered a hunk of platinum and iridium as ever existed, appears to weigh less than it did when it was manufactured in the late 19th century.



Bureau International des Poids et Mesures

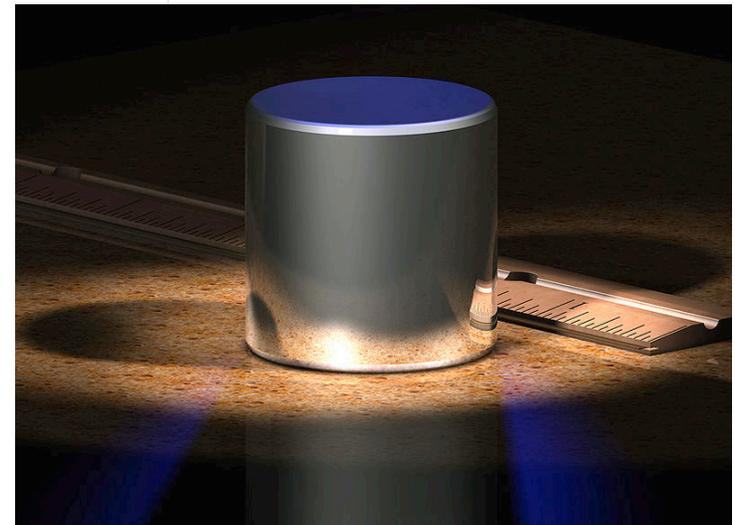
The international prototype of the kilogram resides in Sèvres, France. Its vault can be opened only with three different keys.

“Your guess is as good as mine,” said Dr. Terry Quinn, emeritus director of the International Bureau of Weights and Measures in this town on the fringes of Paris.

It is here that the kilogram — the universal standard against which all other kilograms are measured — resides in controlled conditions set out in 1889, in an underground vault that can be opened only with three different keys possessed by three different people.

The change, discovered when the prototype was compared with its official copies, amounts only to some 50 micrograms, equal to the mass of a smallish grain of sand.

But it shows that the prototype has fallen down on its primary job, to be a beacon of stability in a world of uncertainty.



not good.

From the NY Times  
2/12/2011.

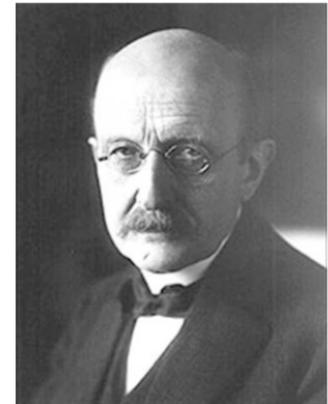
The **Kilogram** is the SI unit of mass.

In 2019, the Kilogram was redefined:

The kilogram, symbol kg, is the SI unit of mass. It is defined by taking the fixed numerical value of Planck's constant  $h$  to be exactly  $6.62607015 \times 10^{-34}$  when expressed in the unit  $\text{J} \cdot \text{s}$ , which is equal to  $\text{kg m}^2 \text{s}^{-1}$

$$E_{\text{photon}} = h\nu = \frac{hc}{\lambda}$$

$$h = 6.62607015 \times 10^{-34} \text{ kg m}^2 \text{ s}^{-1}$$



Max Planck  
1858-1947

From Wikipedia.

# What is a mole?

The OLD SI unit for the amount of a substance, equal to the quantity containing as many chemical units as there are atoms in exactly 12 grams (0.012 kg) of Carbon-12.

This number is based on the kilogram.

Thus, there was no completely accurate measure of Avogadro's number. In 2018, it's value was:

$$N_0 = 6.02214129 \times 10^{23}$$

This has changed in 2019!

## *New definition of the mole*

In 2019 the mole was redefined. One mole now contains exactly  $6.02214076 \times 10^{23}$  elementary entities. This number is the fixed numerical value of the Avogadro constant,  $N_A$  in units of  $\text{mol}^{-1}$ . This number is called Avogadro's number.

$$N_A = 6.02214076 \times 10^{23} \text{ mol}^{-1}$$

*This number is NOT based on the kilogram.*

*So how do we calculate molecular weight?*

# What is a Dalton?

The *dalton or unified atomic mass unit* (SI symbol: Da) is *STILL* defined as exactly  $1/12$  of the mass of an unbound neutral atom of carbon-12 in its nuclear and electronic ground state and at rest.

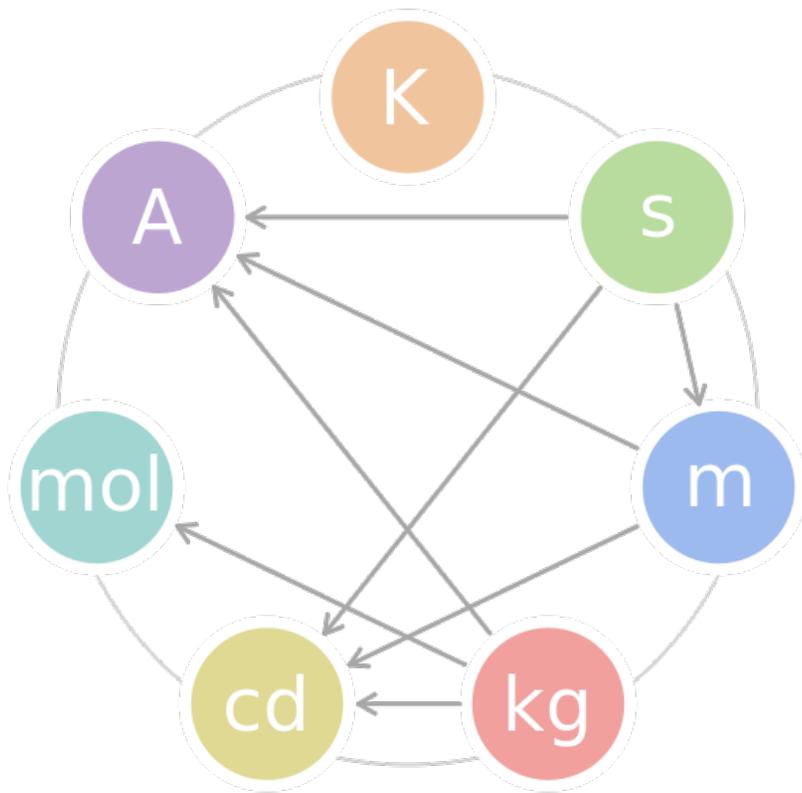
A mass of 1 Da is also referred to as *the atomic mass constant* and denoted by  $m_u$ . It used to be 1 g/mol; i.e. the weight of a mole of carbon-12 was 12 g exactly. *This is no longer true in 2019!*

As of 2019, the SI definition of mole changed in such a way that the *molar mass constant is no longer exactly 1 g/mol*. However, the difference is insignificant for all practical purposes. According to the SI, the value of  $m_u$  now depends on the mass of one atom of carbon-12, which must be determined experimentally. As of May 2019, the 2018 CODATA recommended value of  $M_u$  is  $0.999999999965(30) \times 10^{-3} \text{ kg} \cdot \text{mol}^{-1}$

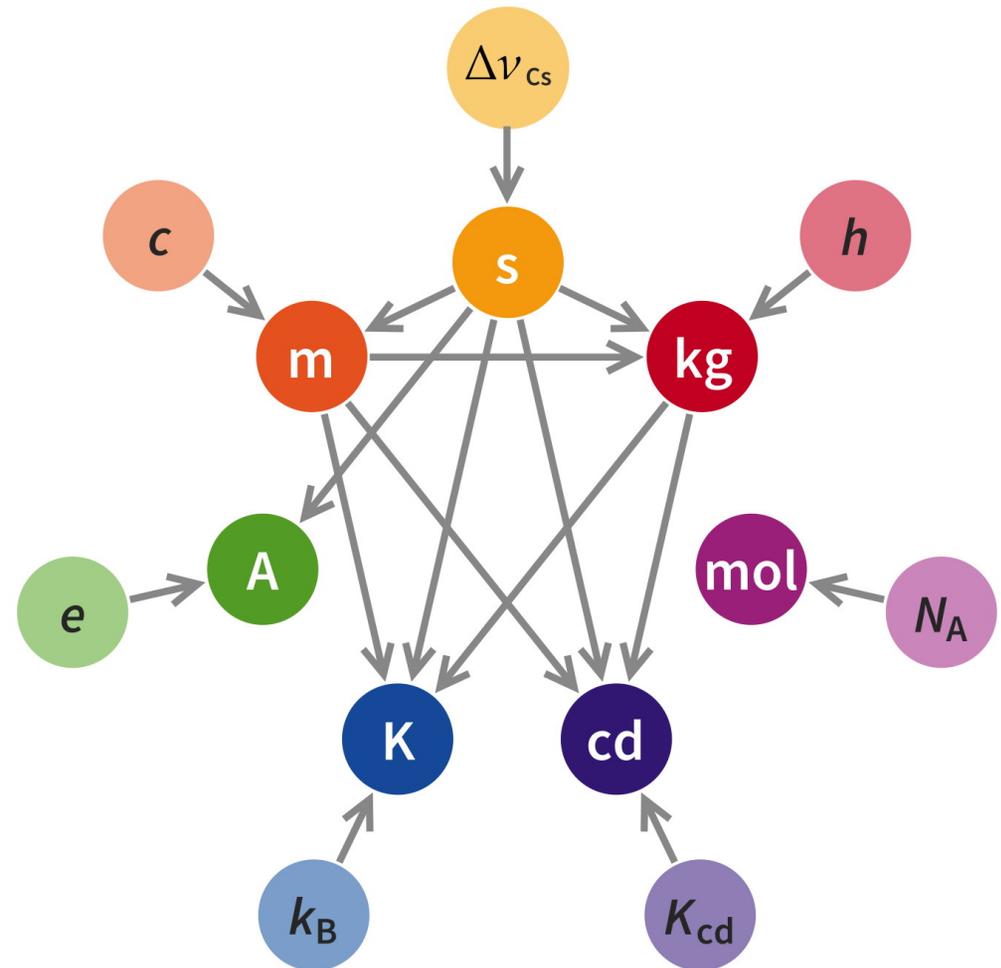
For more see: [https://en.wikipedia.org/wiki/2019\\_redefinition\\_of\\_the\\_SI\\_base\\_units](https://en.wikipedia.org/wiki/2019_redefinition_of_the_SI_base_units)

Well, it's better now, albeit a bit complicated!

Old SI units



New SI



For us, the MW of C is stil 12 g/mol.