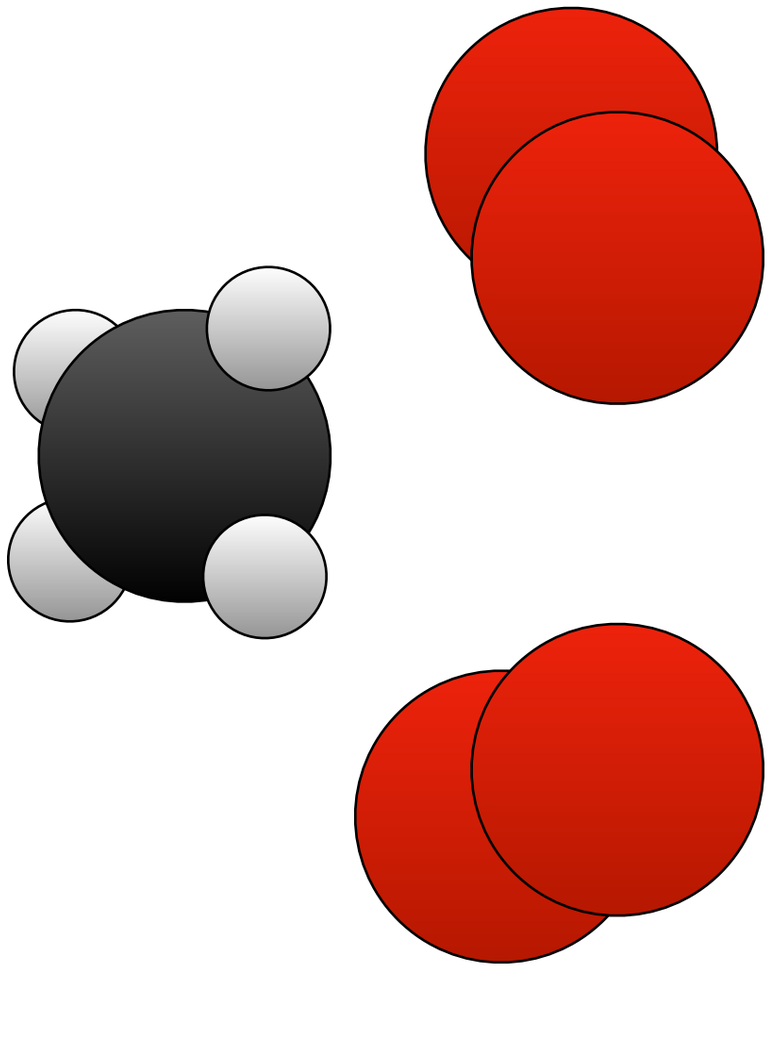
Science informatique

CM10

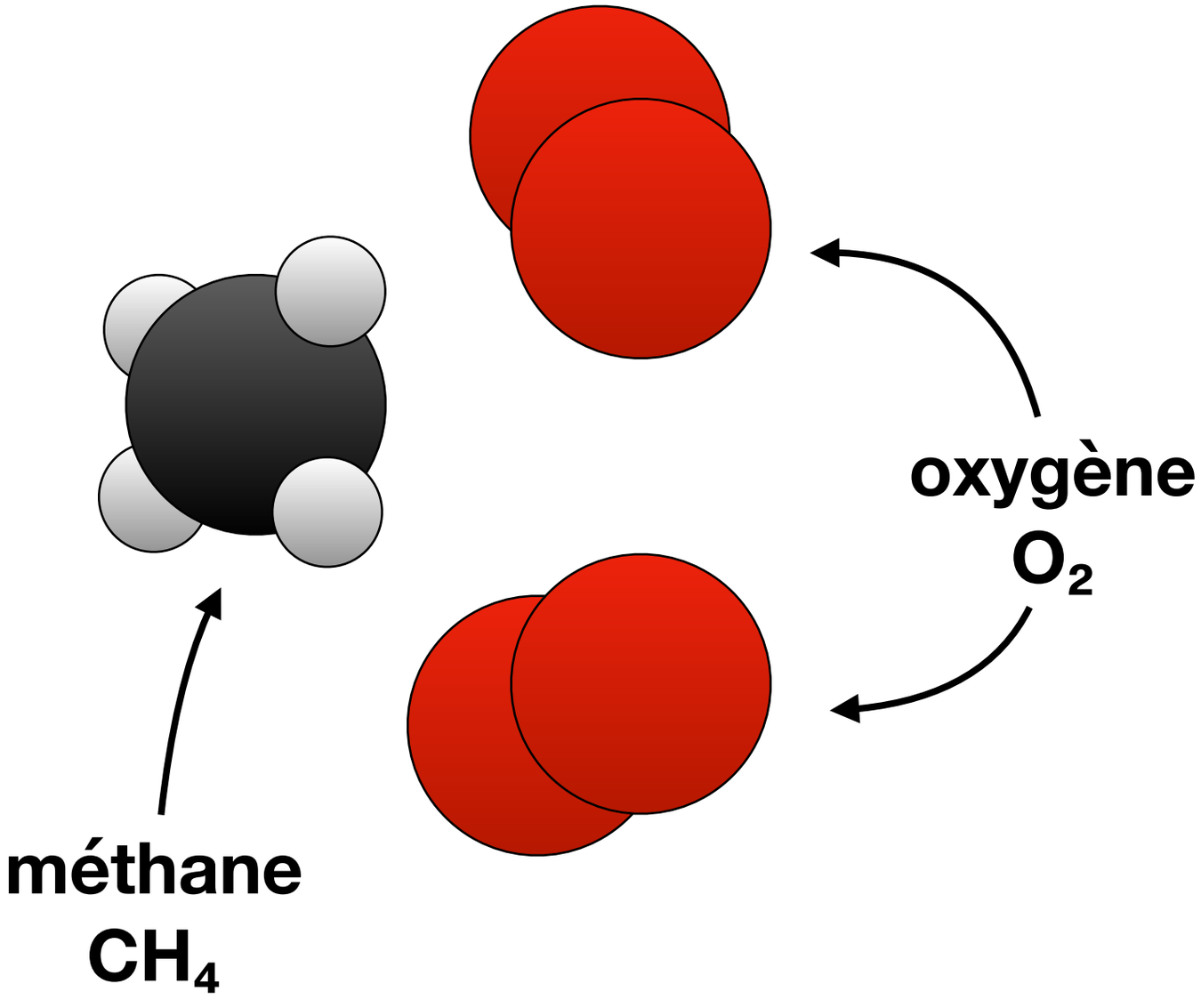
Antonio E. Porreca
aeporreca.org/scienceinfo

Réactions chimiques

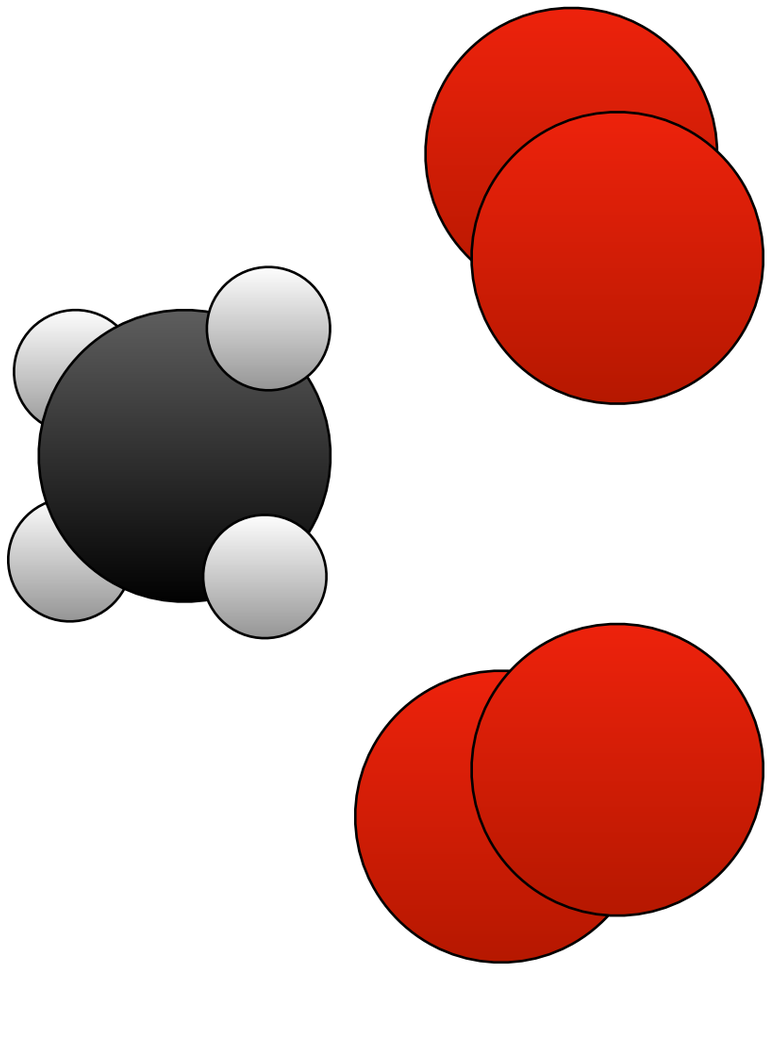
Combustion du méthane



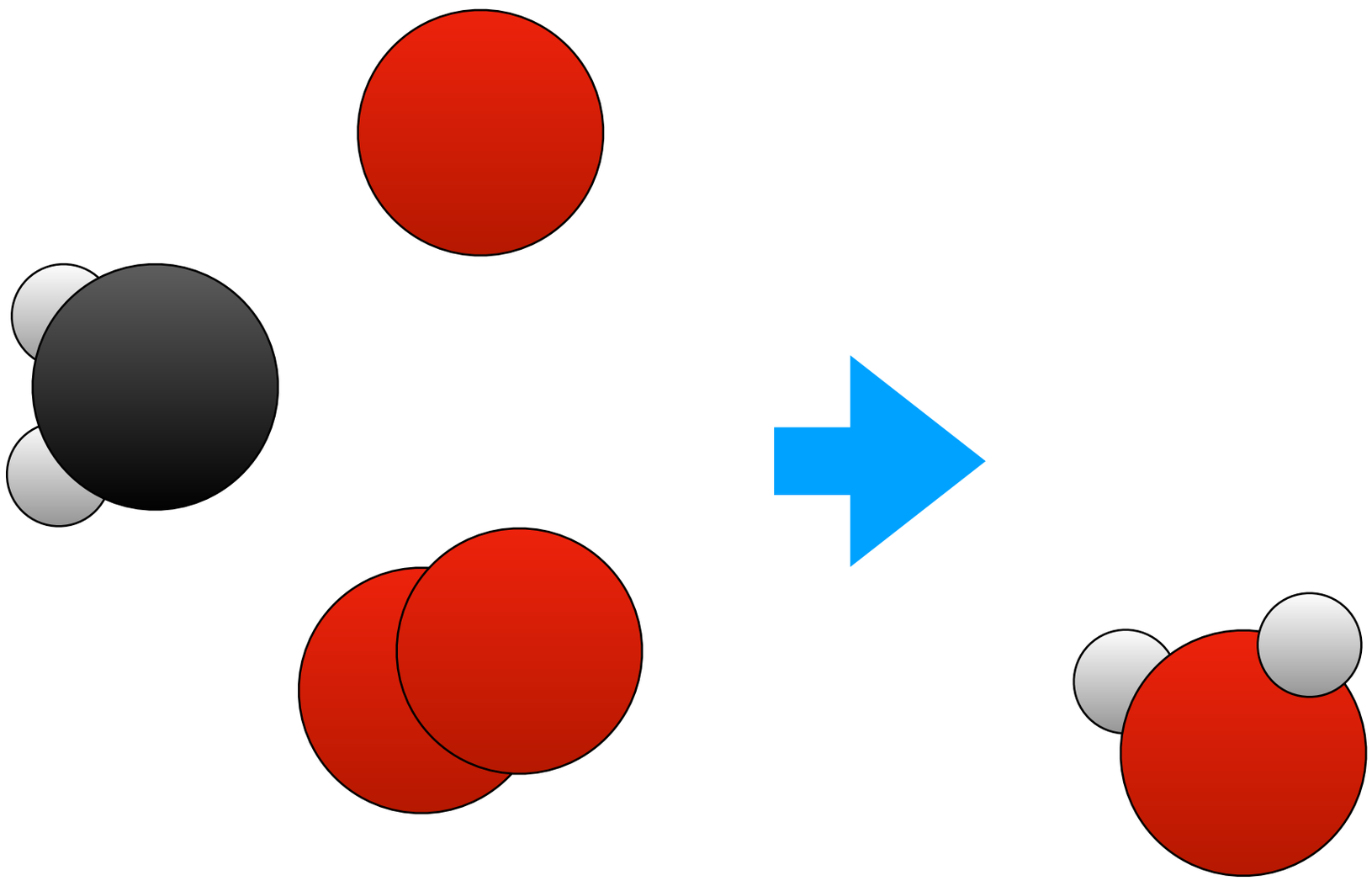
Combustion du méthane



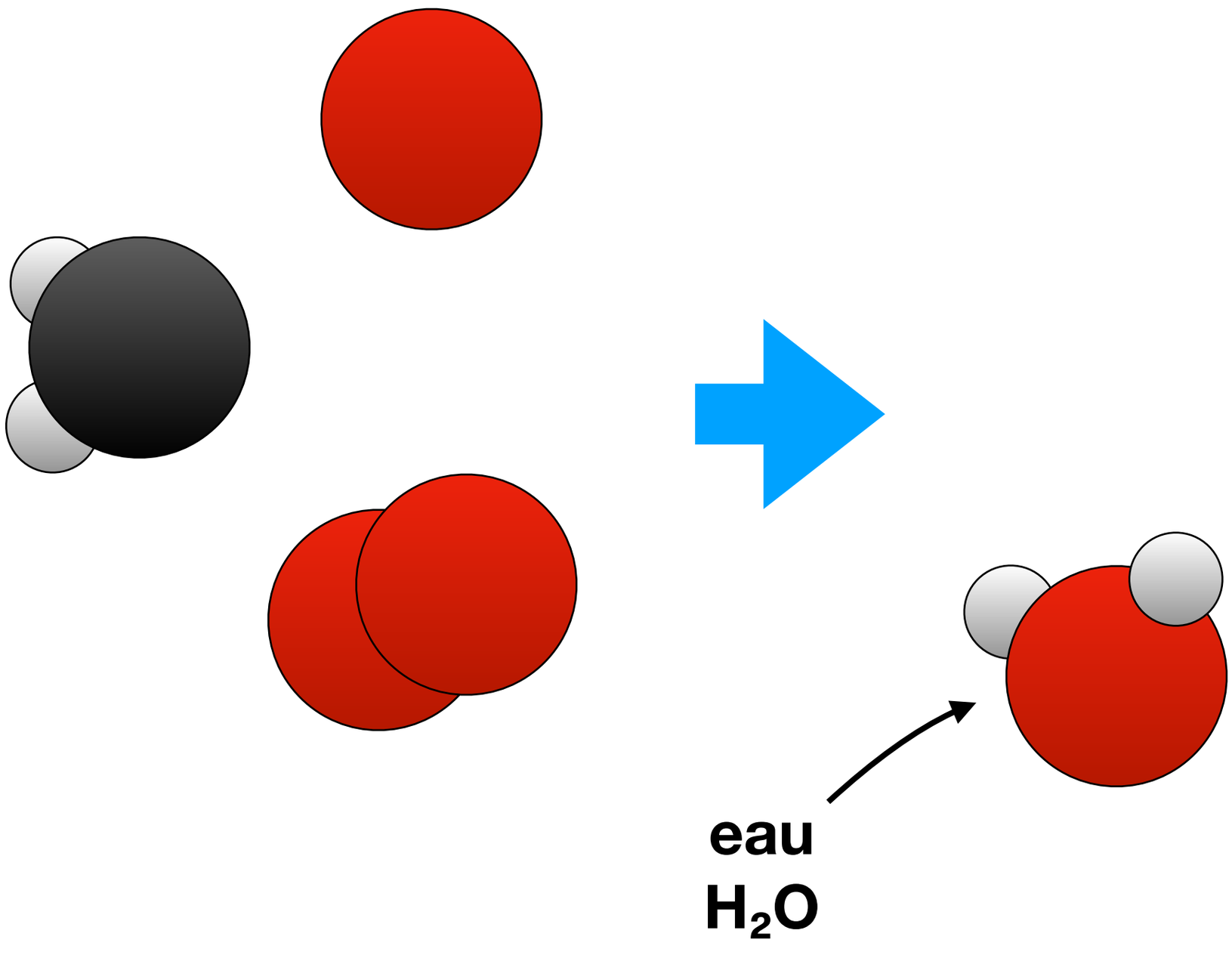
Combustion du méthane



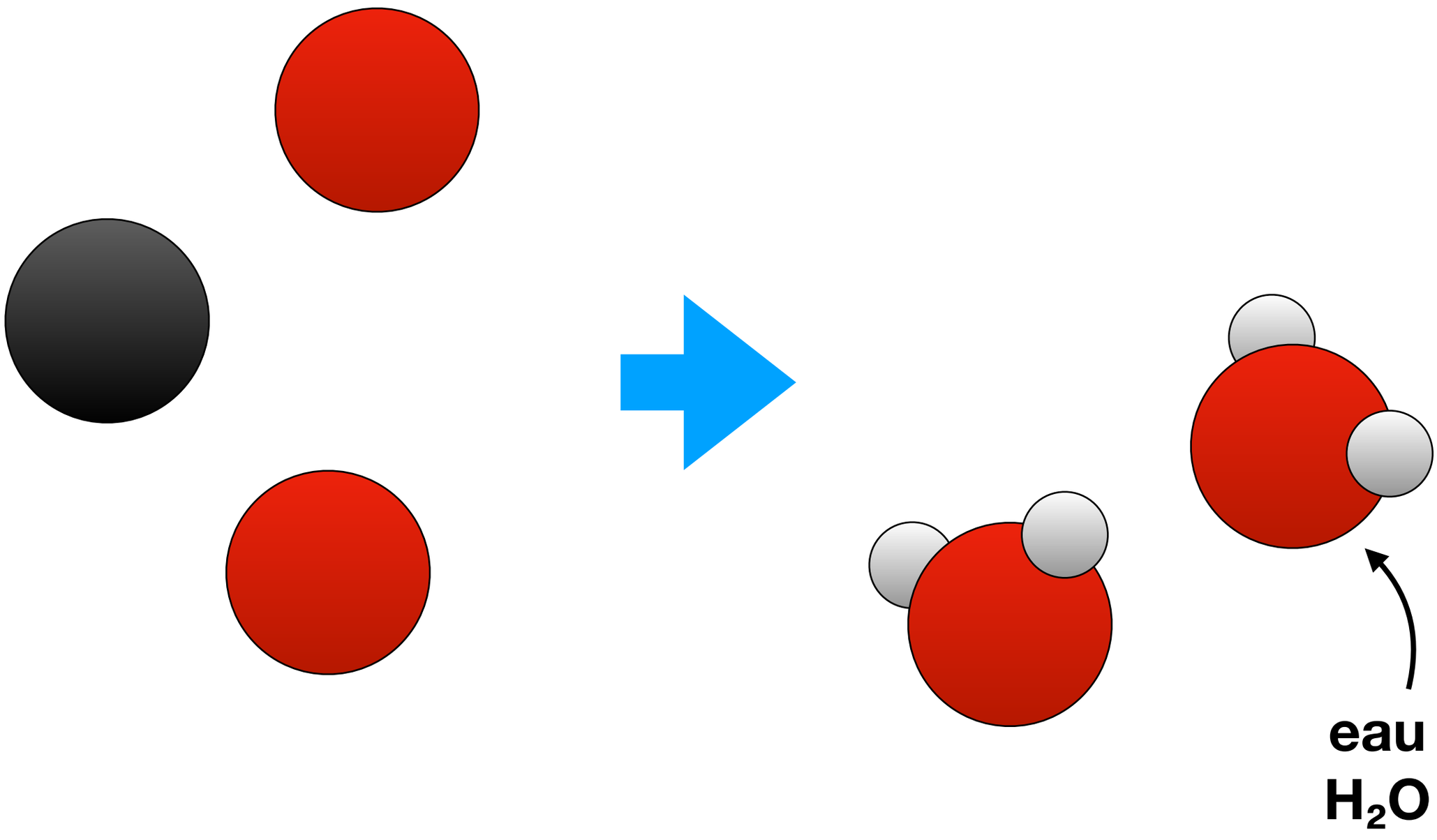
Combustion du méthane



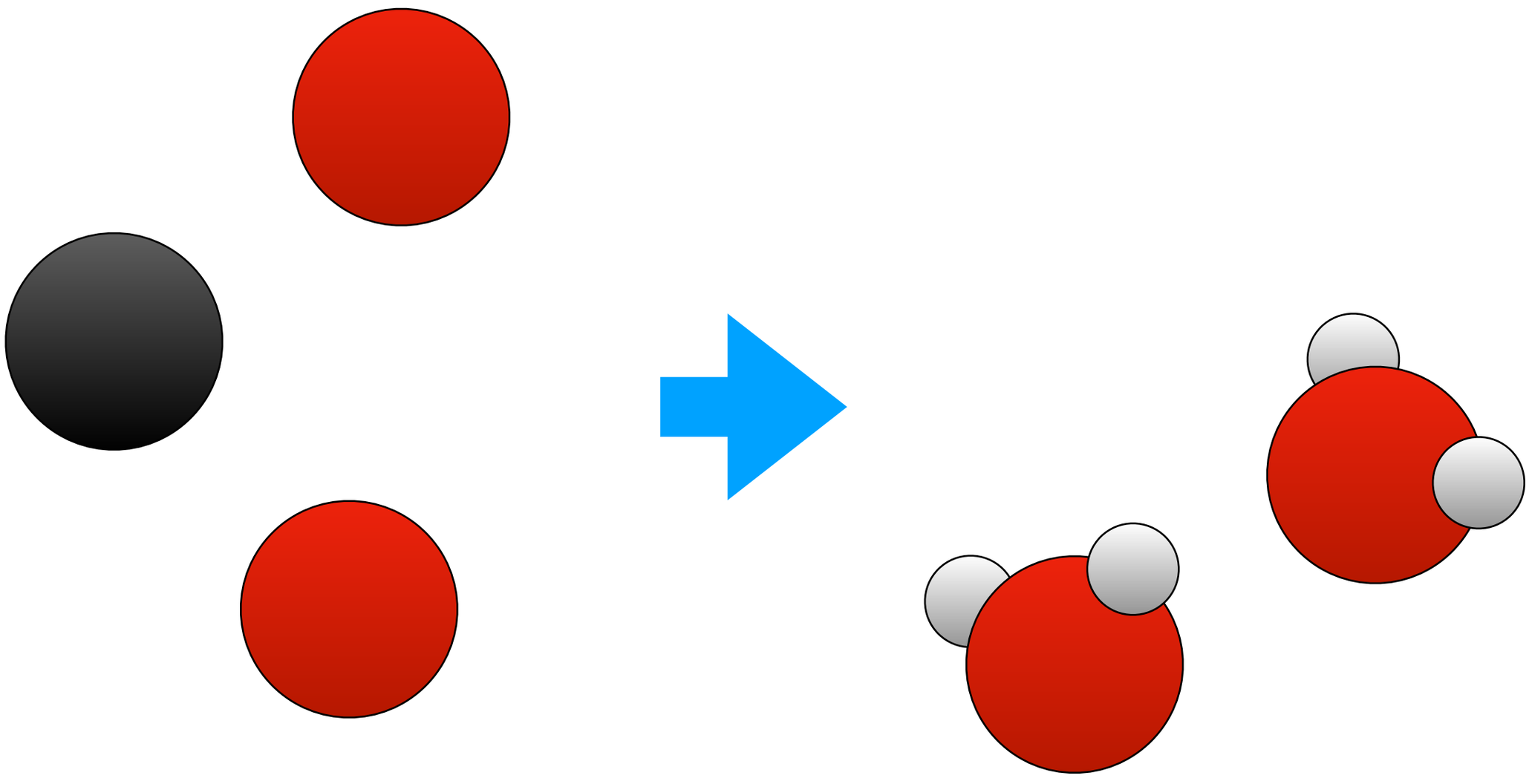
Combustion du méthane



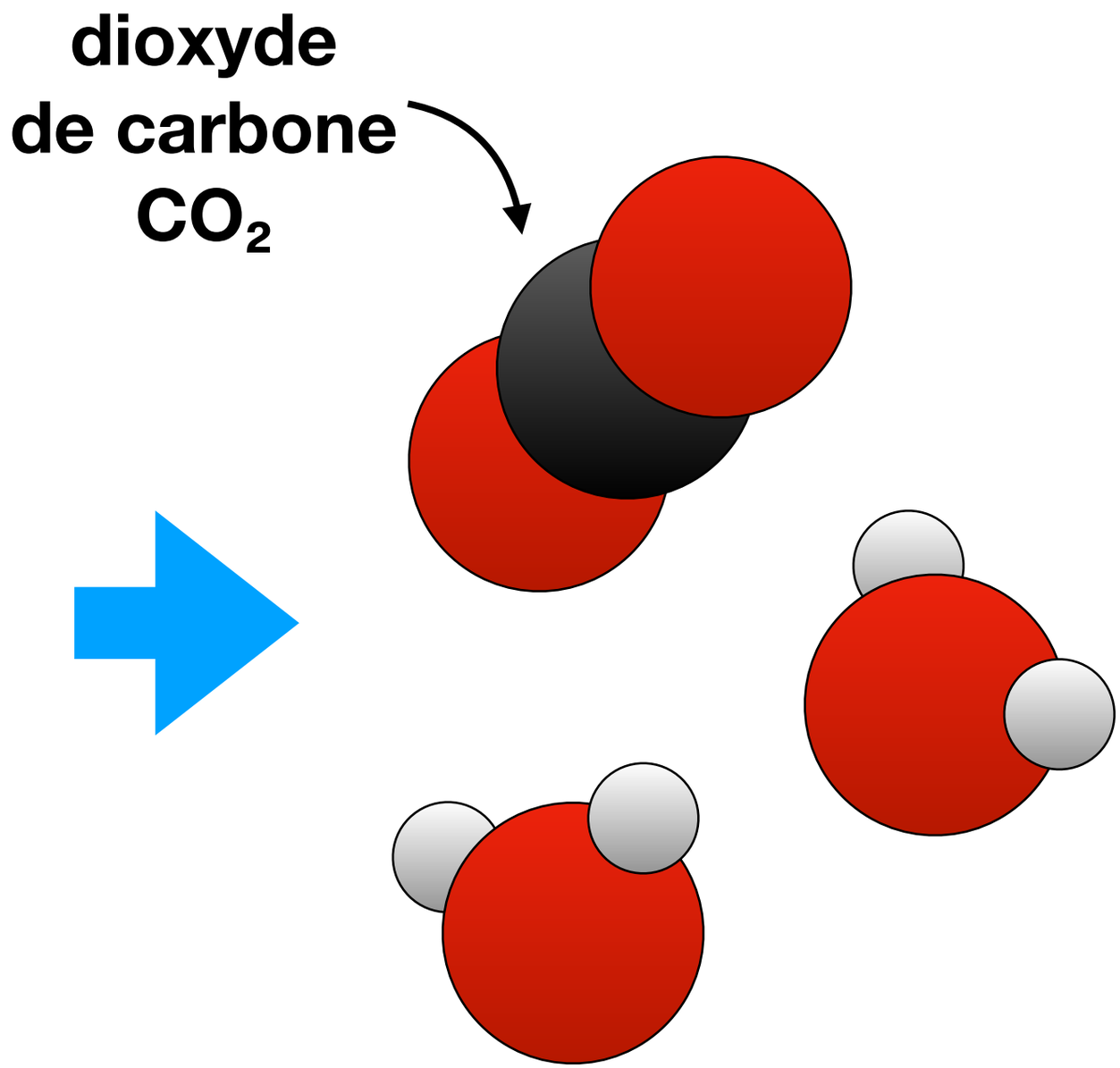
Combustion du méthane



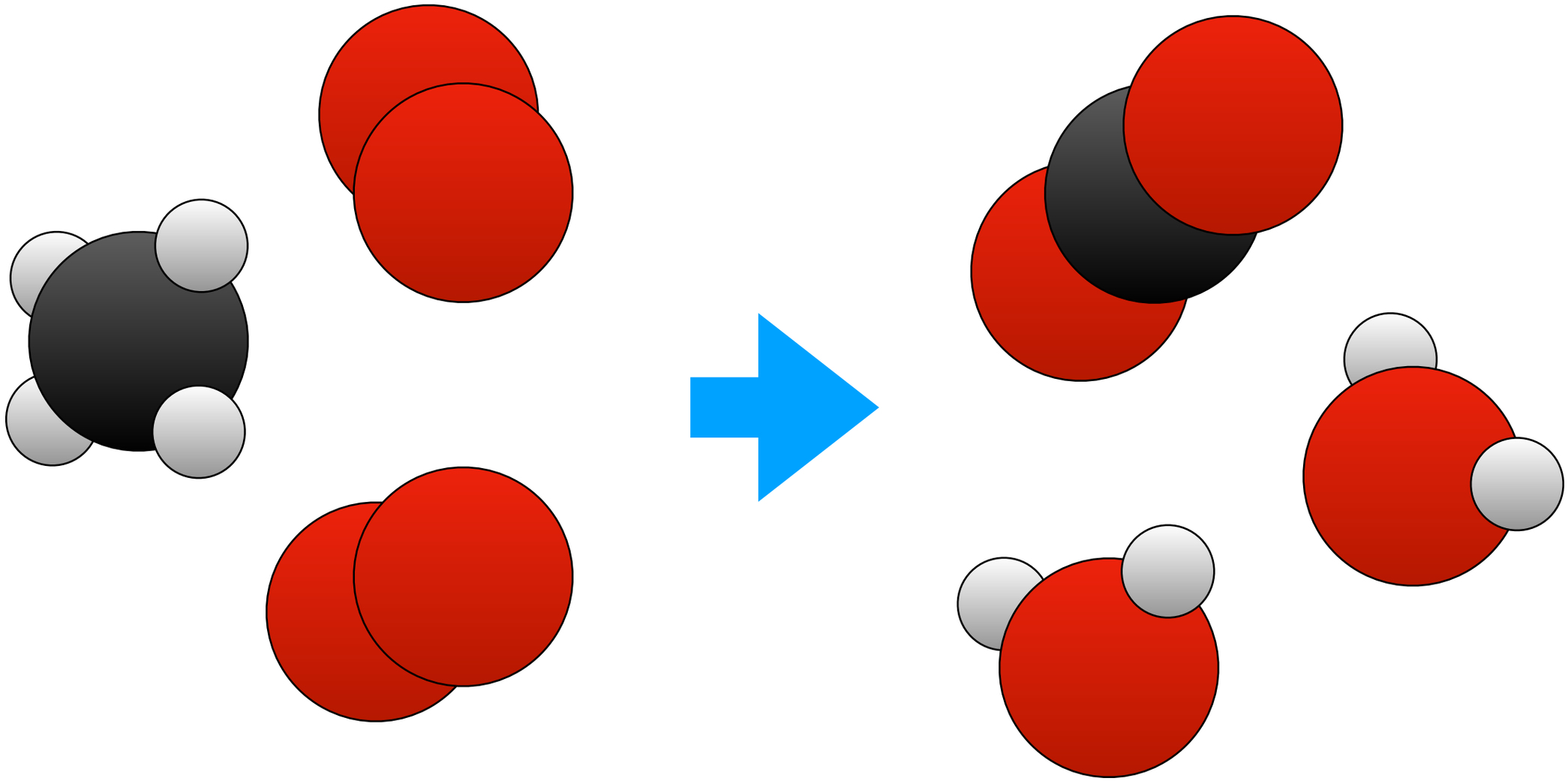
Combustion du méthane



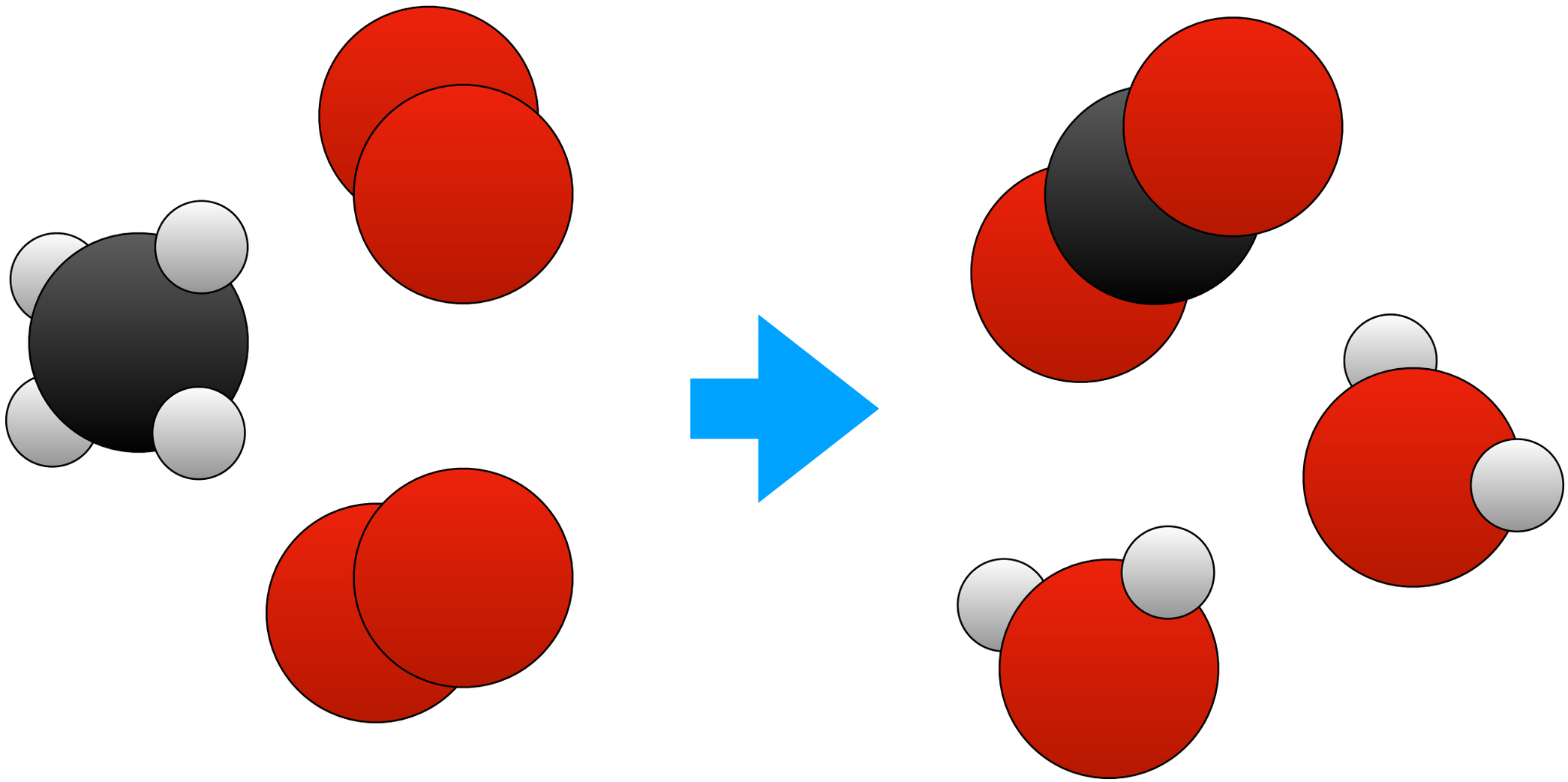
Combustion du méthane



Combustion du méthane



Combustion du méthane



$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$$

Réactions chimiques abstraites

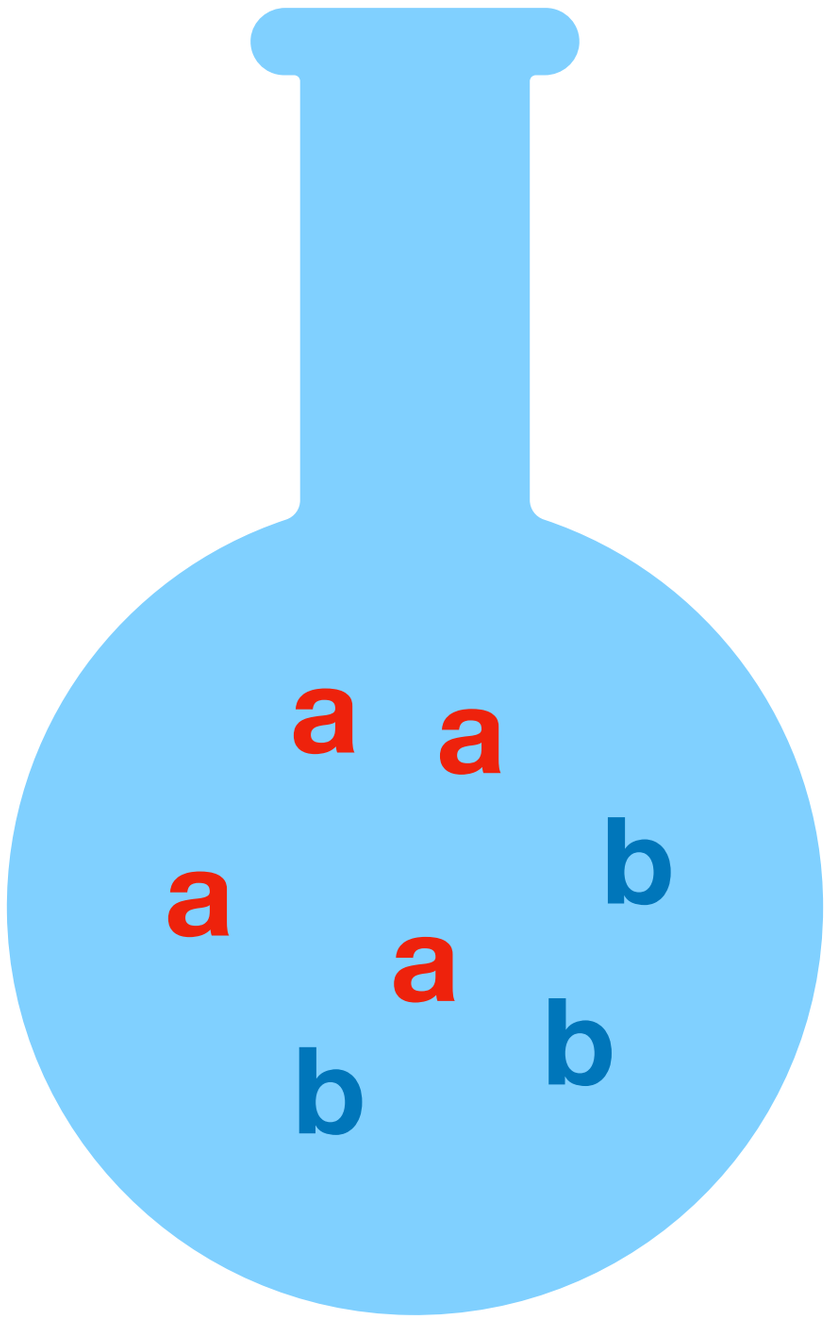
$$2\,a + b \rightarrow c + d + e$$

$$a + c \rightarrow 2\,b + d$$

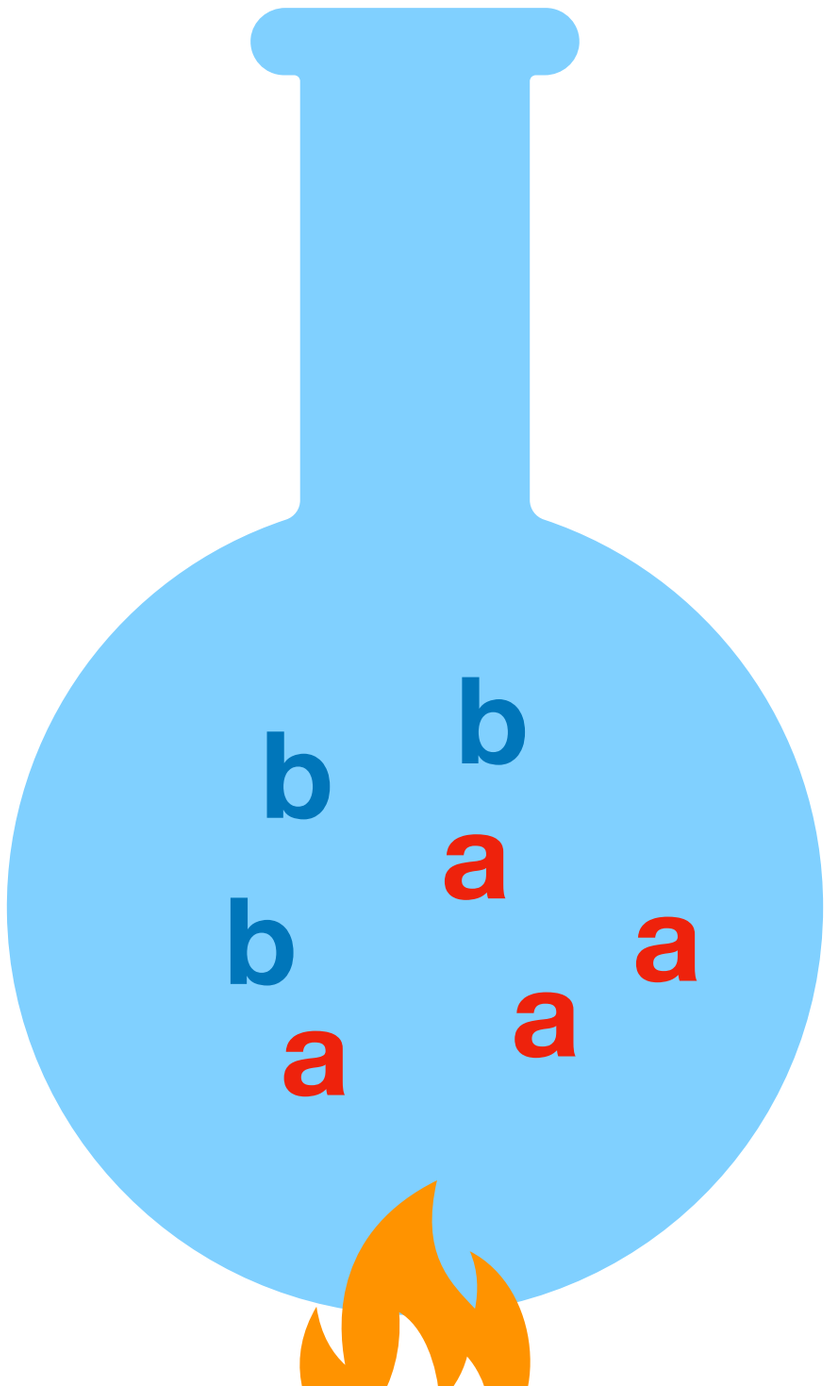
Calcul avec les réactions chimiques

On prend un ballon

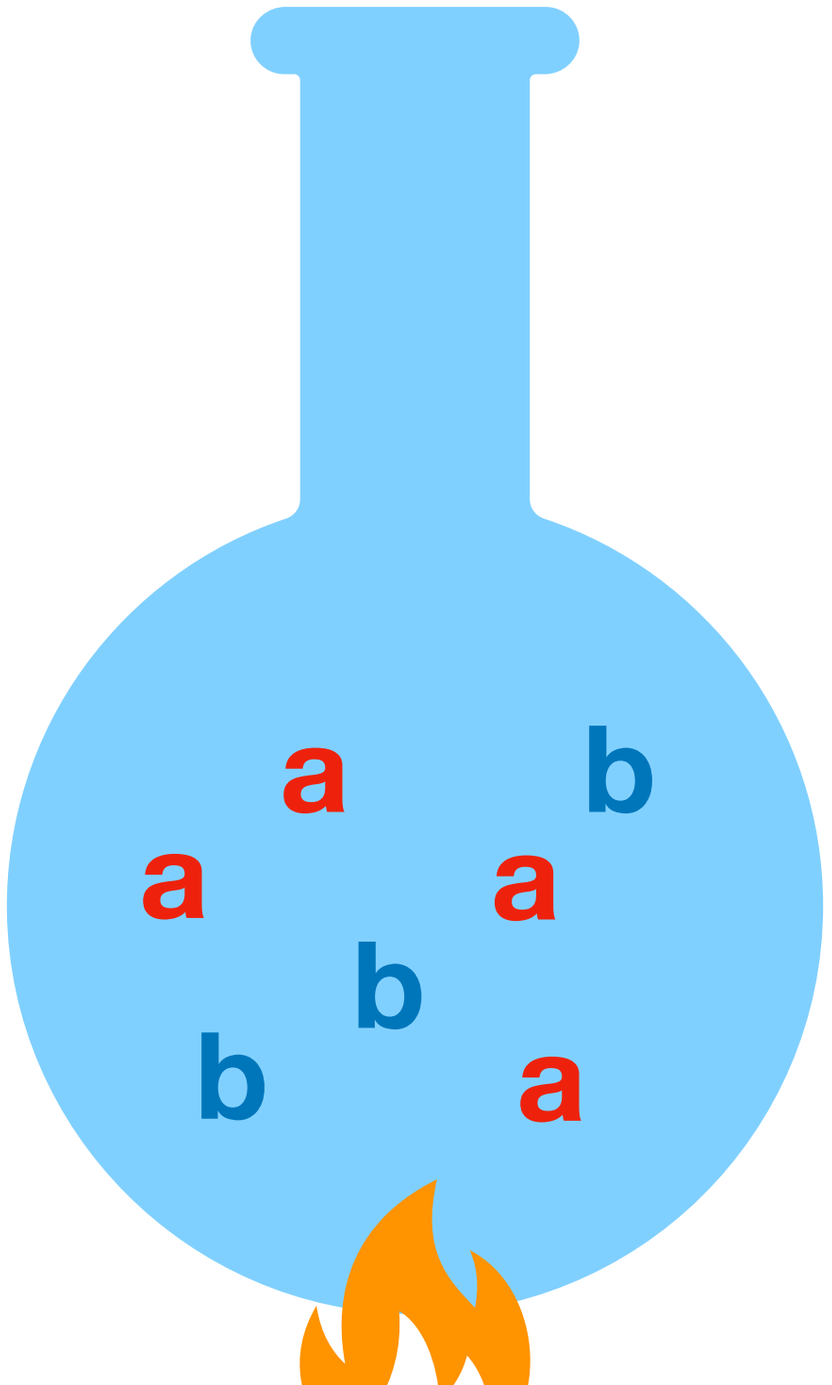
On y verse des molécules



On chauffe



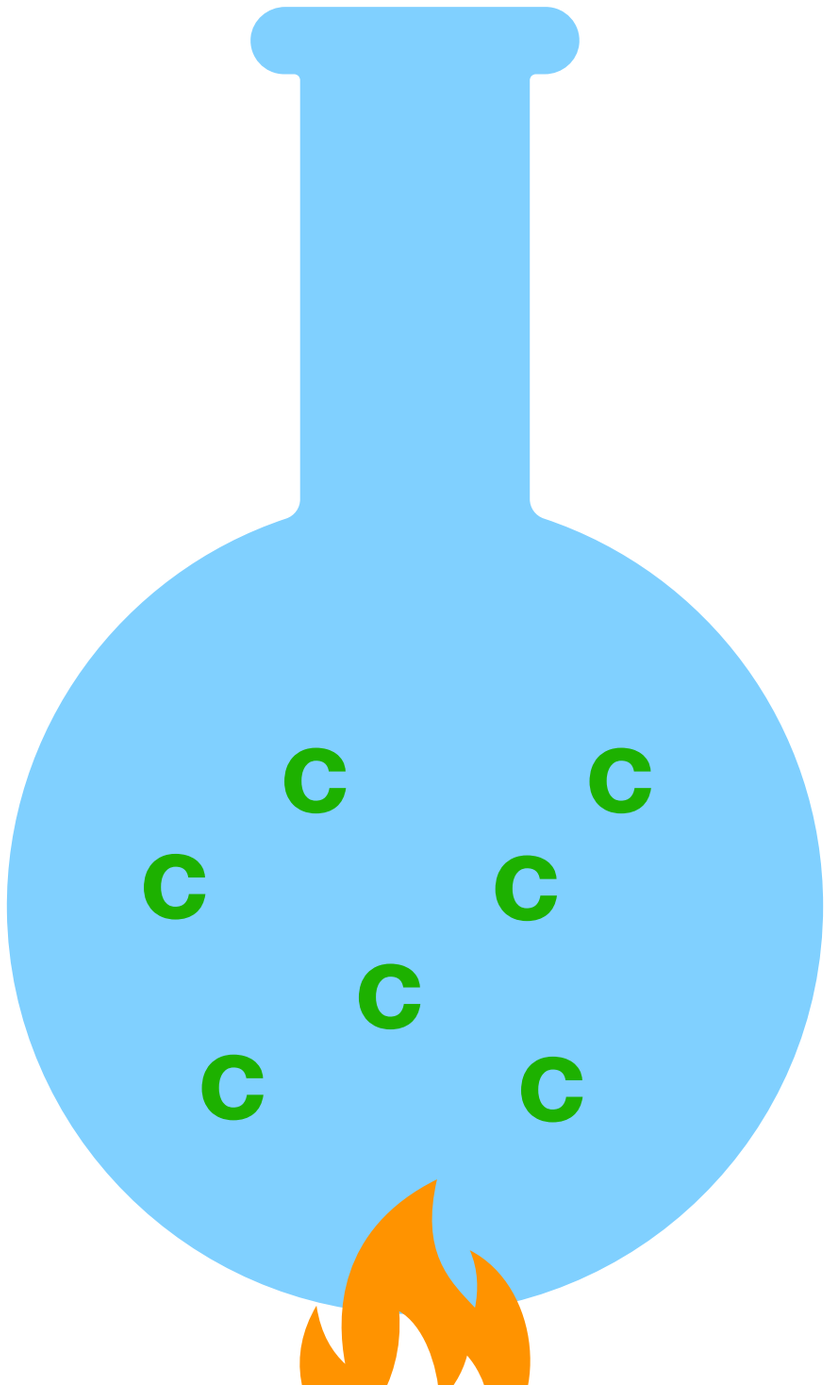
Les réactions on lieu simultanément



a → c

b → c

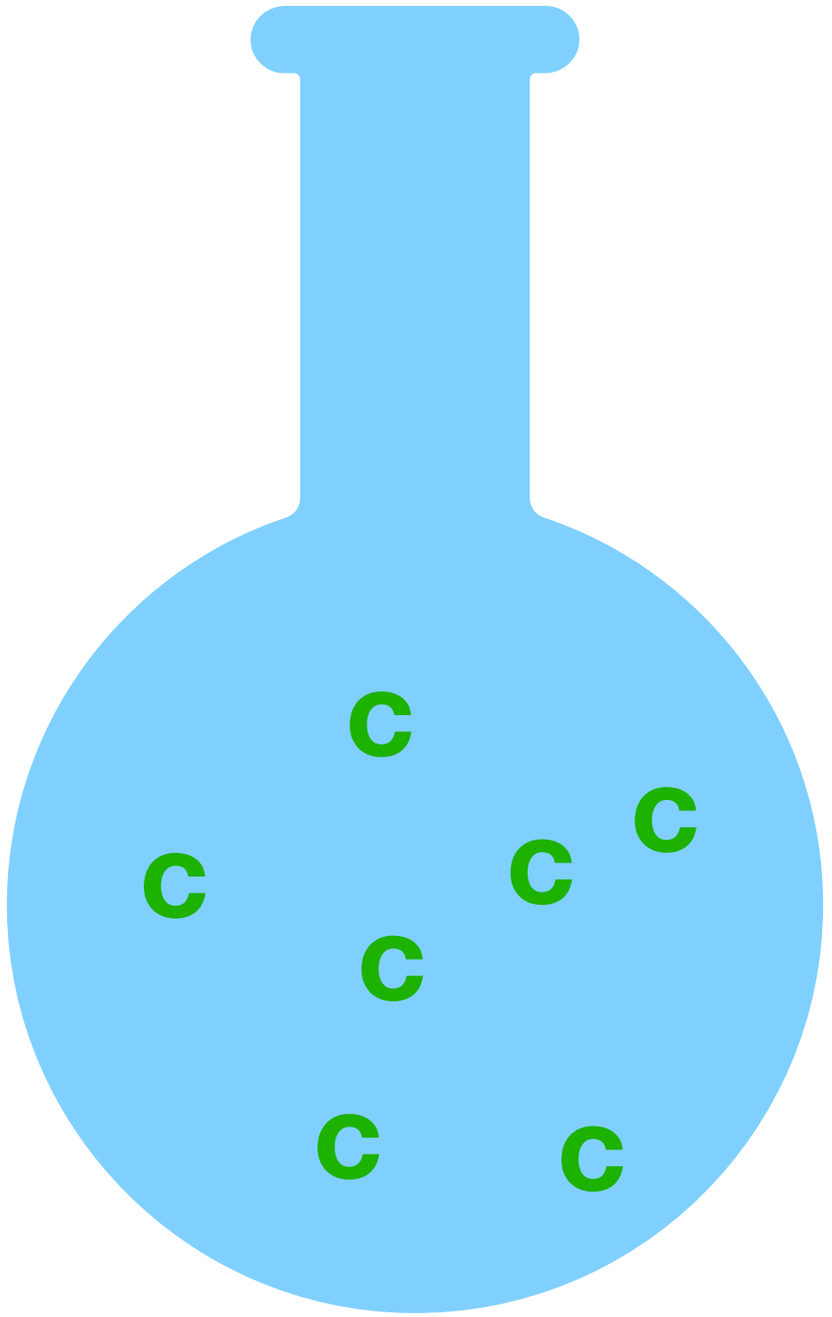
Les réactions on lieu simultanément



a → c

b → c

On laisse refroidir
et on interprète le résultat

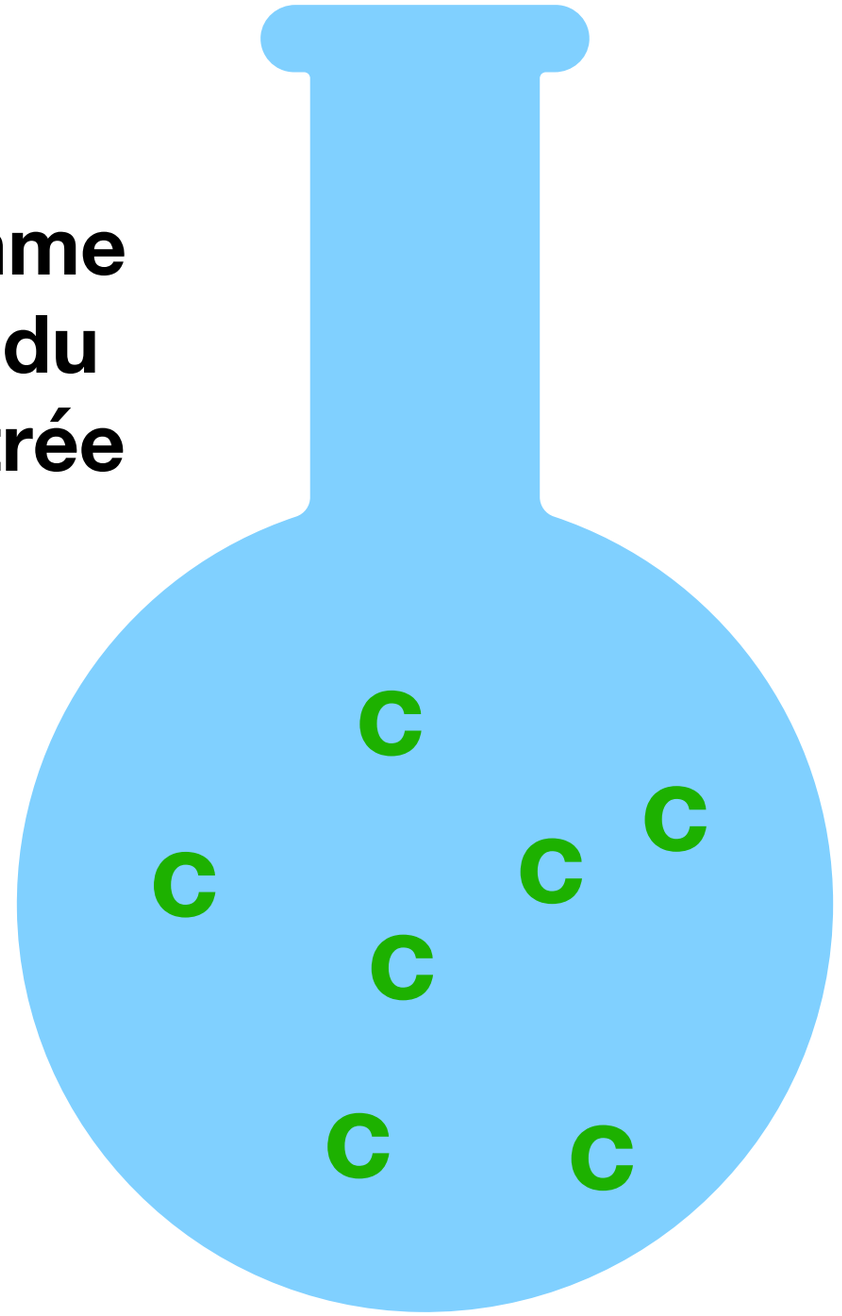


a → c

b → c

On laisse refroidir
et on interprète le résultat

le nombre de c en sortie est la somme du nombre de a et du nombre de b en entrée



a → c

b → c

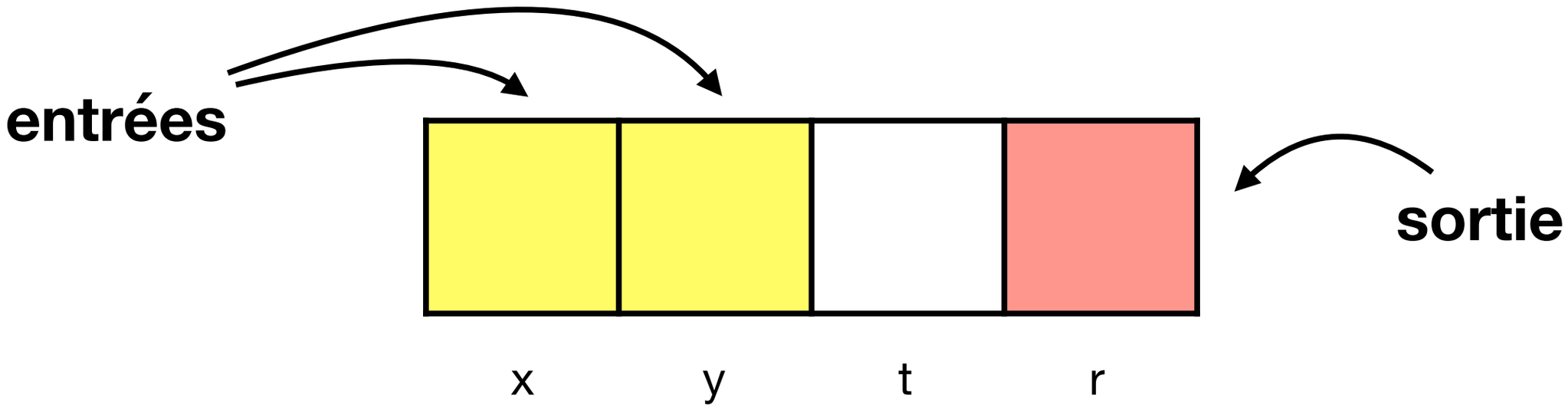
Exercice 3 du TD8

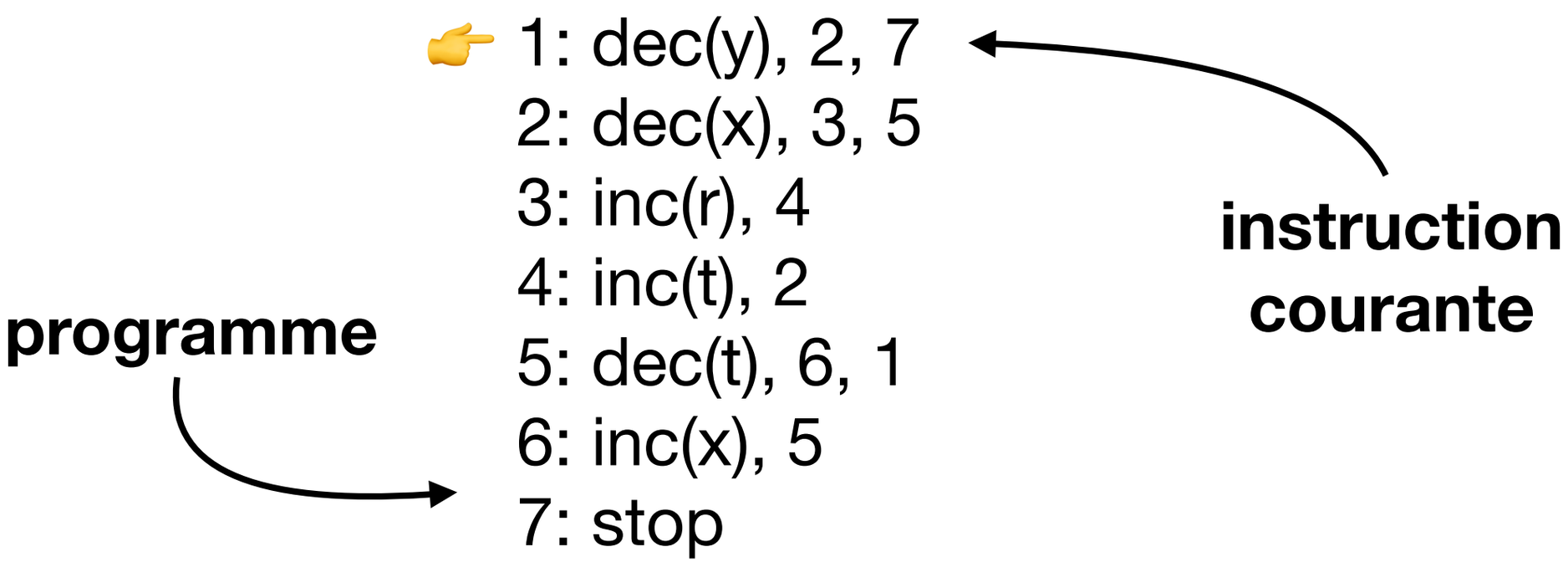
Calculs complexes avec les réactions chimiques

Exercice 4 du TD8

Interlude : machines à registres

Machines à registres





Trois types d'instructions

3: inc(r), 4

instruction 3 :
incrémente le registre r
et passe à l'instruction 4

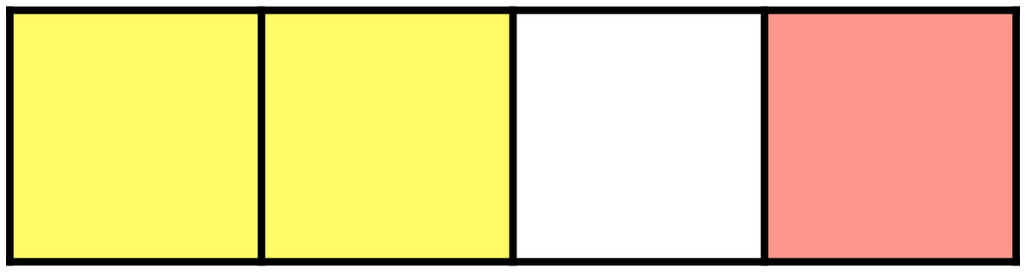
5: dec(t), 6, 1

instruction 4 : si le registre t
est supérieur à 0, alors
décrémente-le et passe
à l'instruction 6, sinon laisse-le
à 0 et passe à l'instruction 1

7: stop

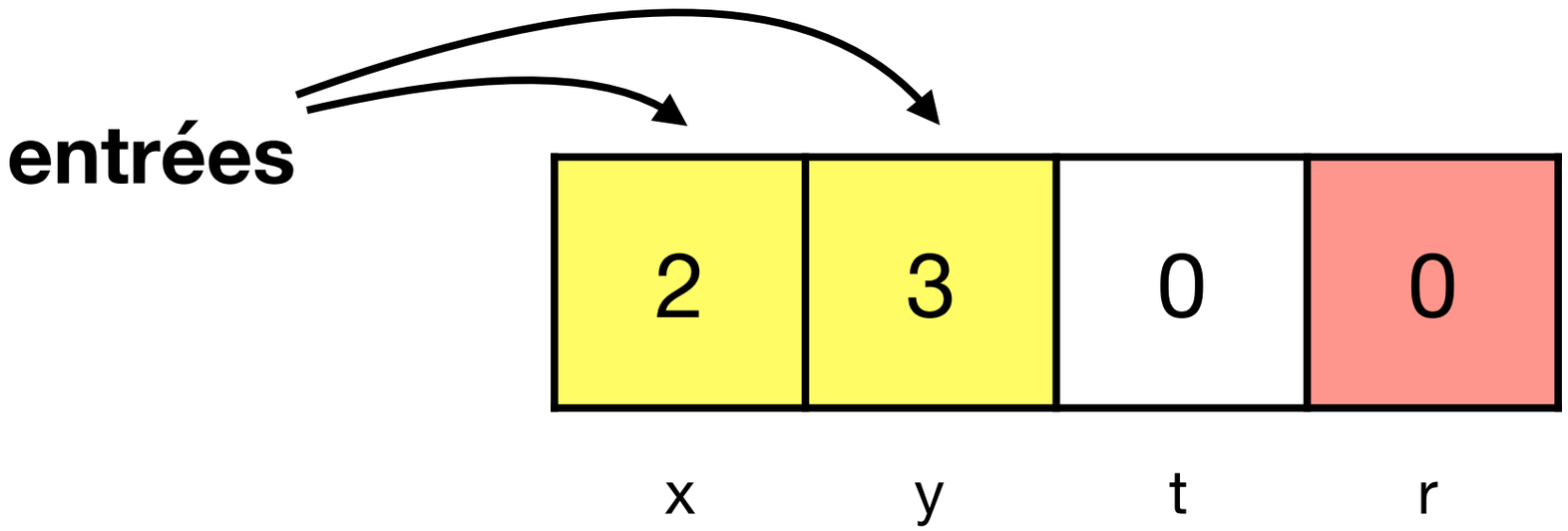
instruction 7 : on s'arrête

Machines à registres



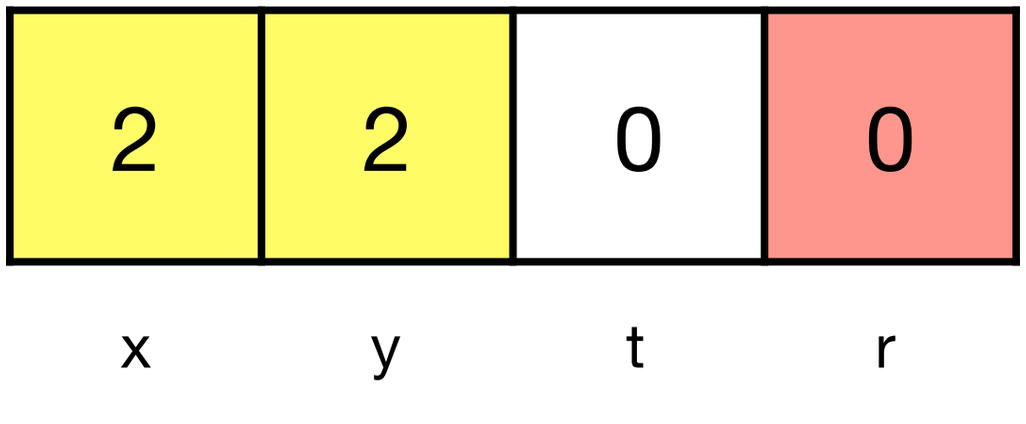
👉 1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



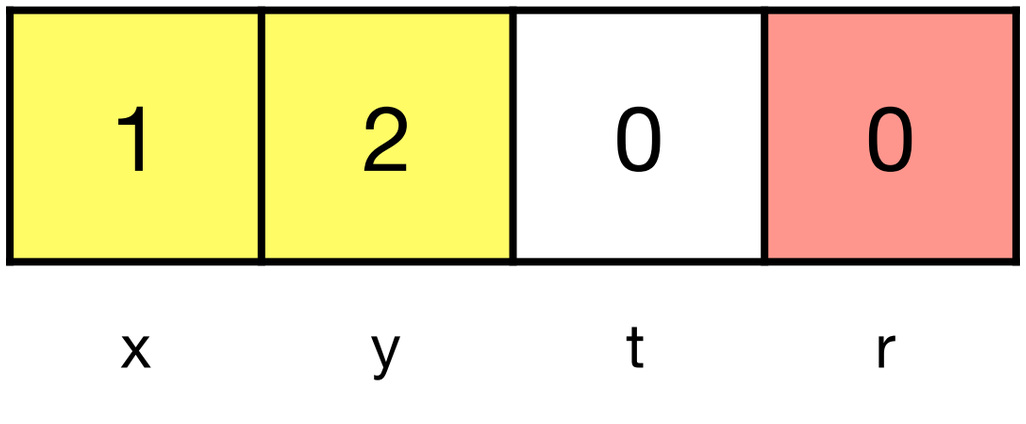
👉 1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



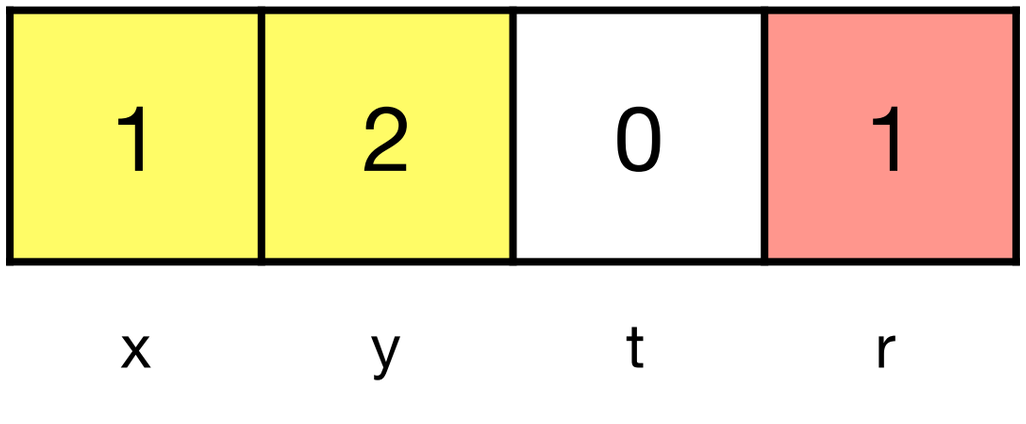
1: dec(y), 2, 7
👉 2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



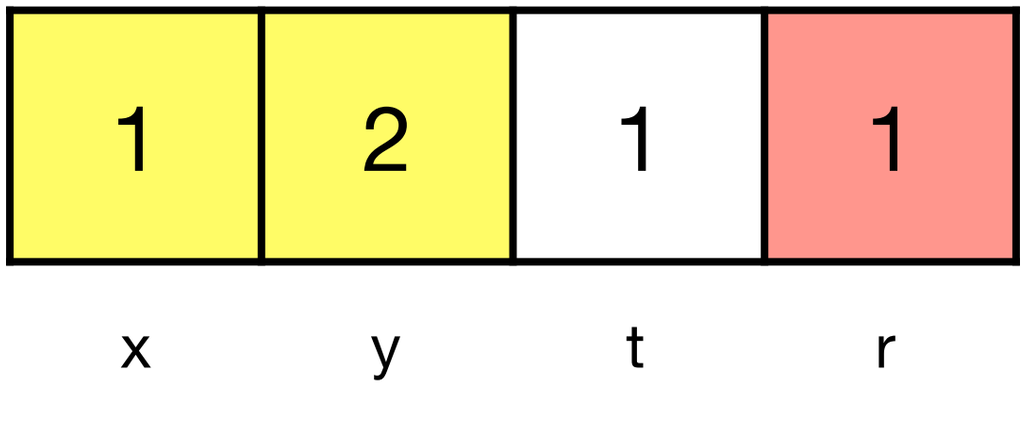
1: dec(y), 2, 7
2: dec(x), 3, 5
👉 3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



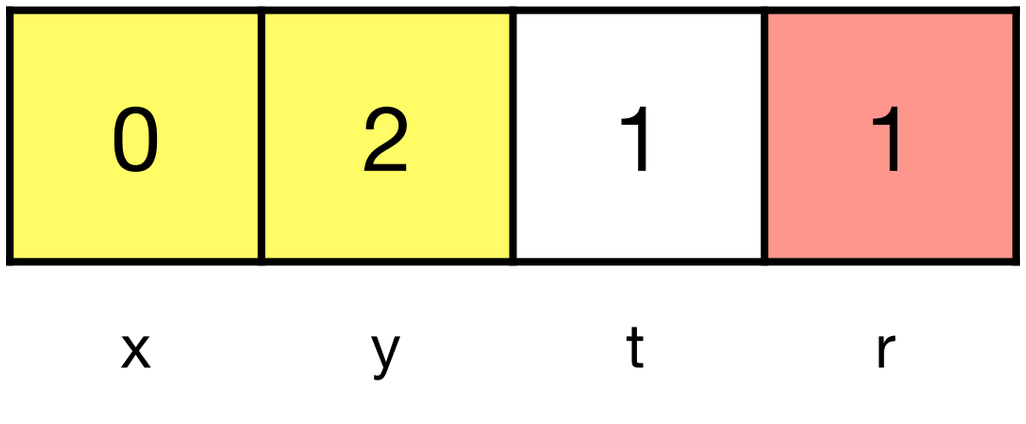
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
👉 4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



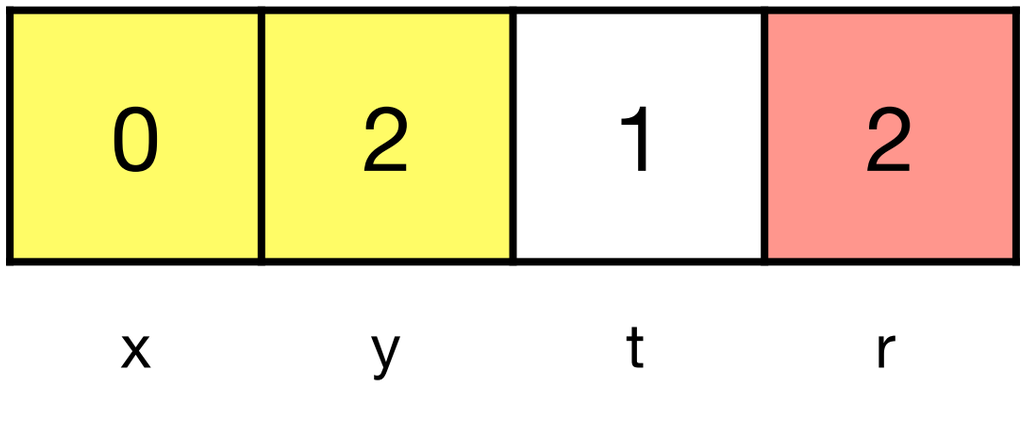
1: dec(y), 2, 7
👉 2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



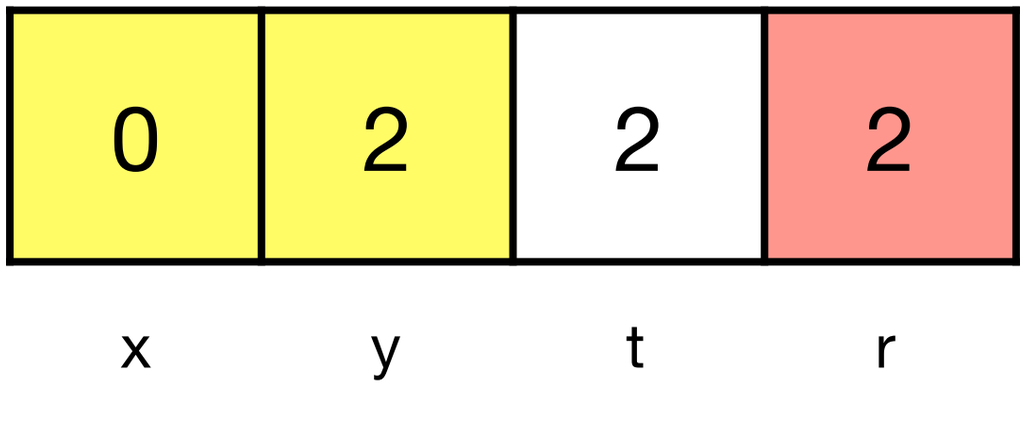
1: dec(y), 2, 7
2: dec(x), 3, 5
👉 3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



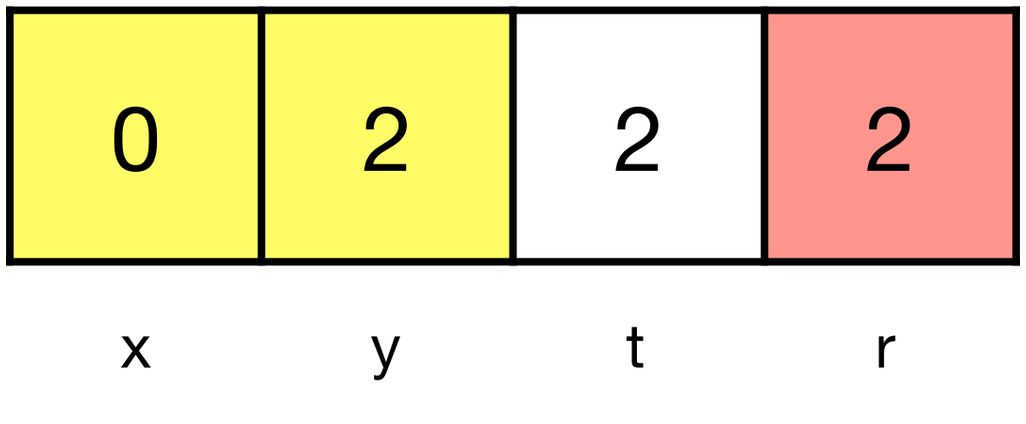
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
👉 4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



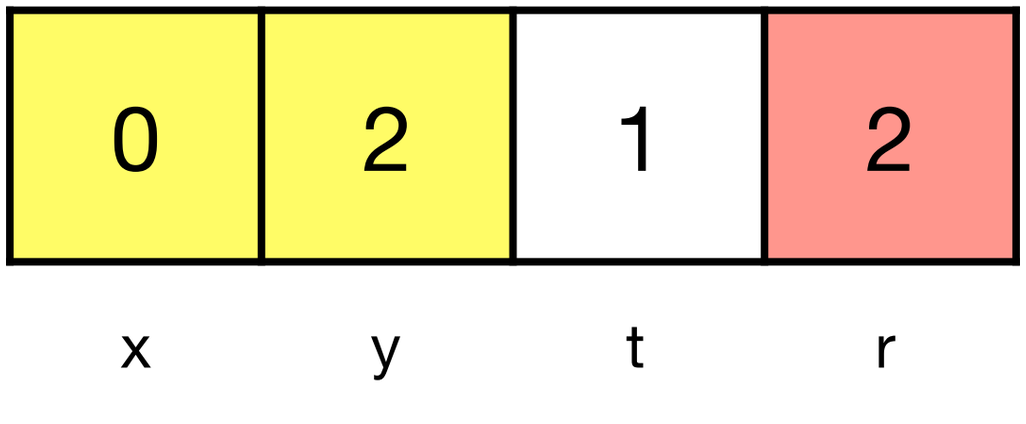
1: dec(y), 2, 7
👉 2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



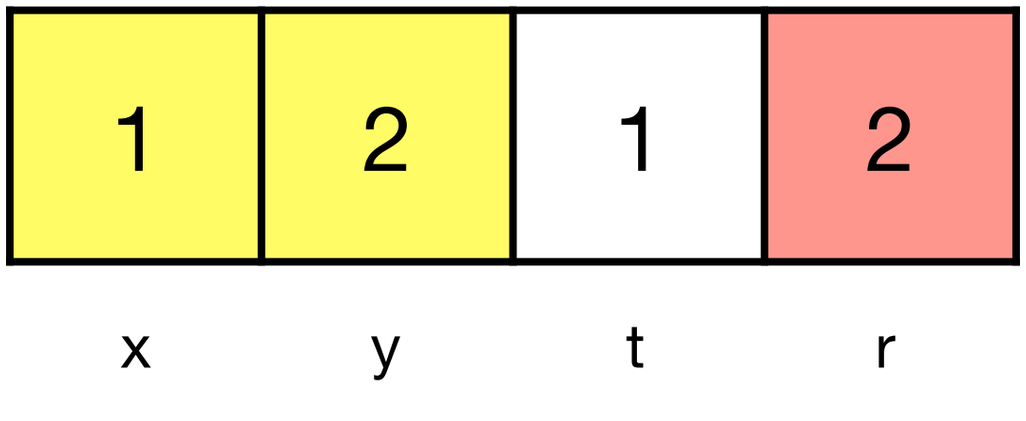
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



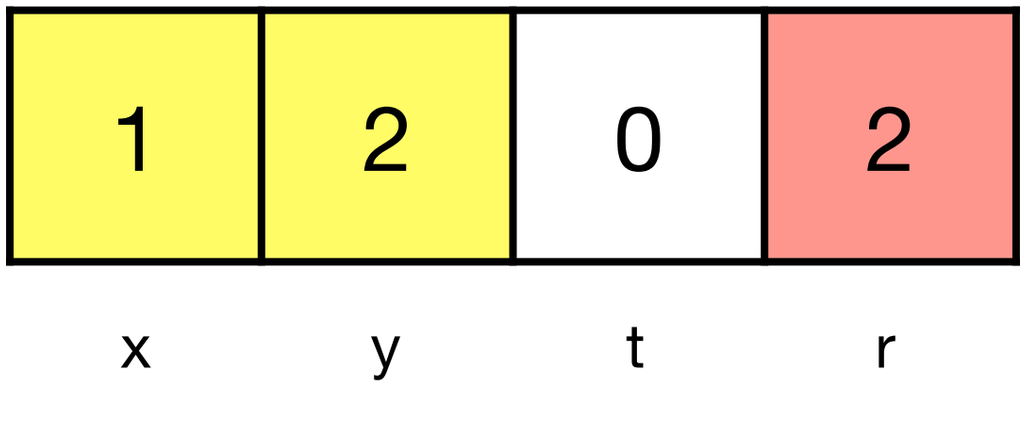
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
👉 6: inc(x), 5
7: stop

Machines à registres



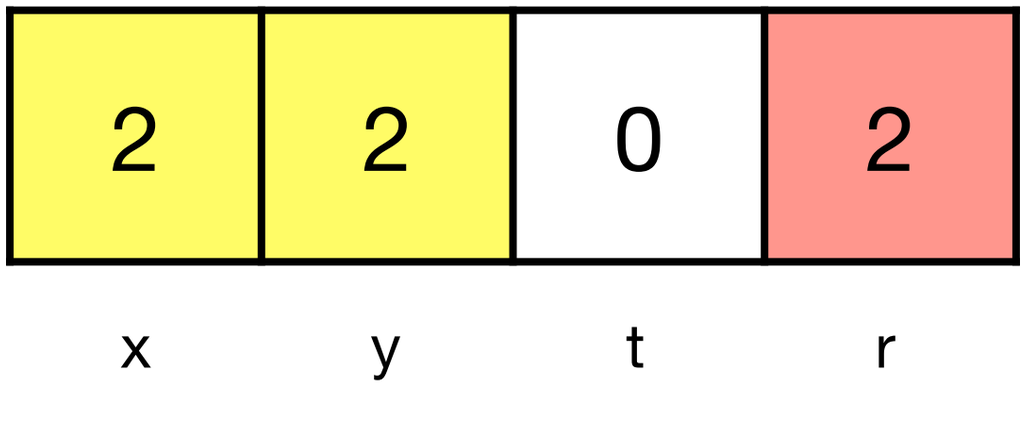
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



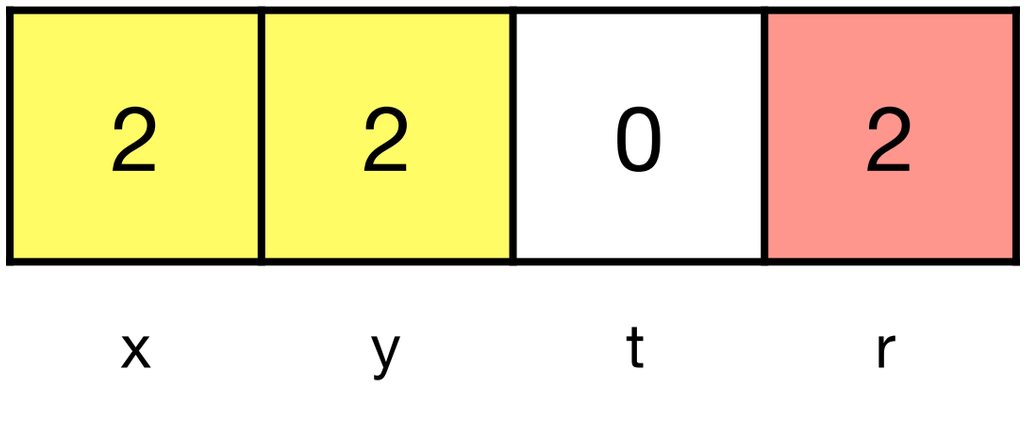
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
👉 6: inc(x), 5
7: stop

Machines à registres



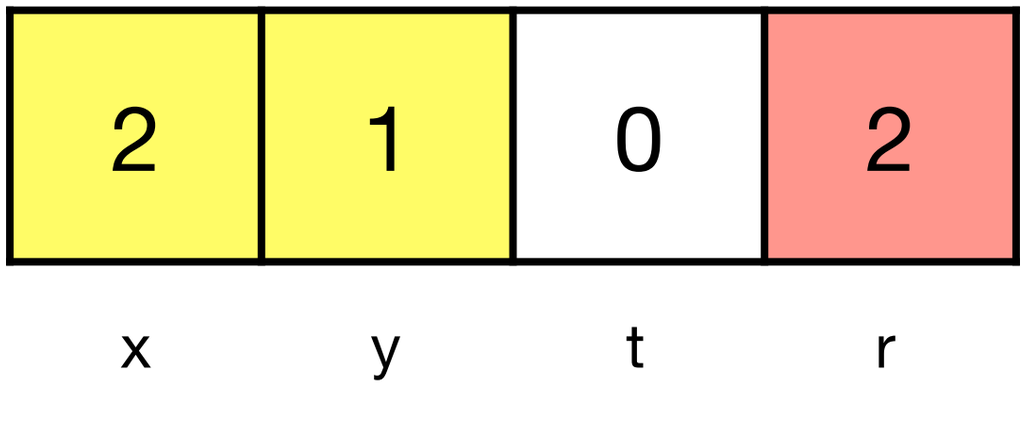
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



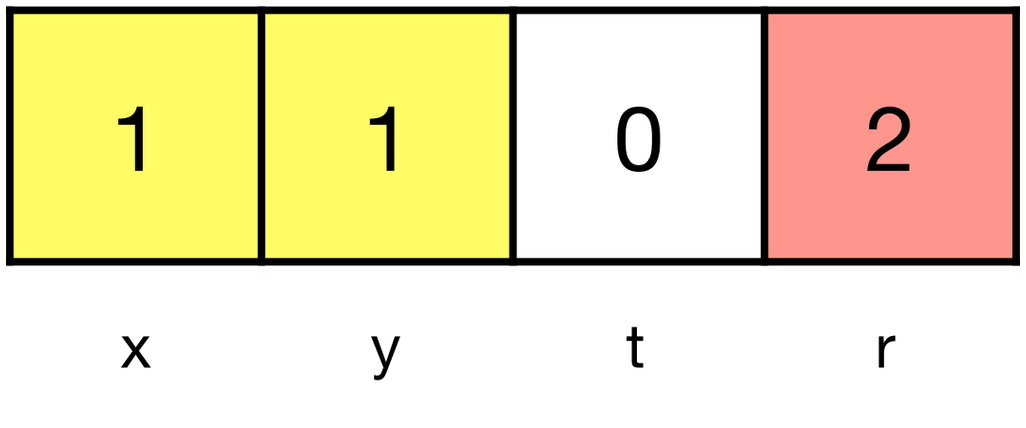
👉 1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



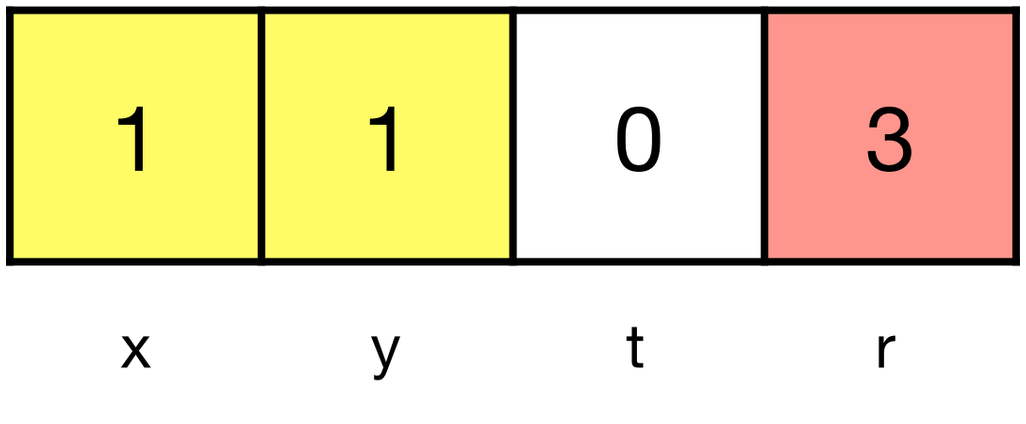
1: dec(y), 2, 7
👉 2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



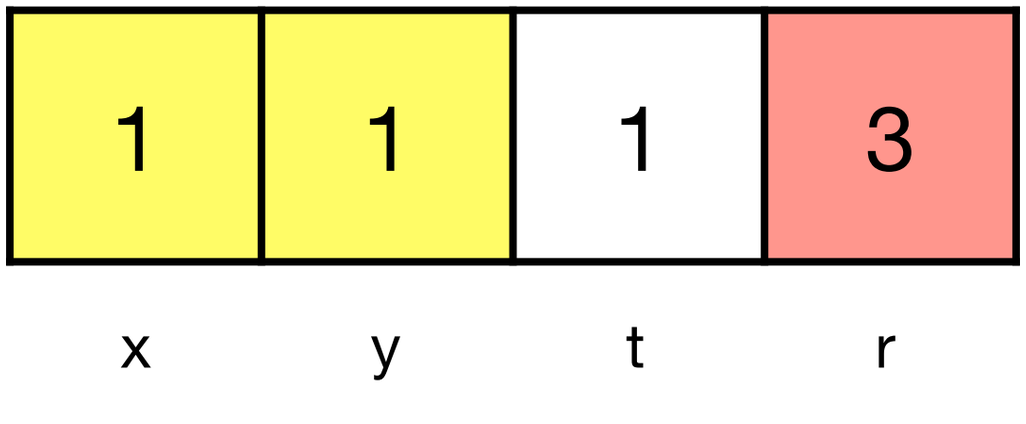
1: dec(y), 2, 7
2: dec(x), 3, 5
👉 3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



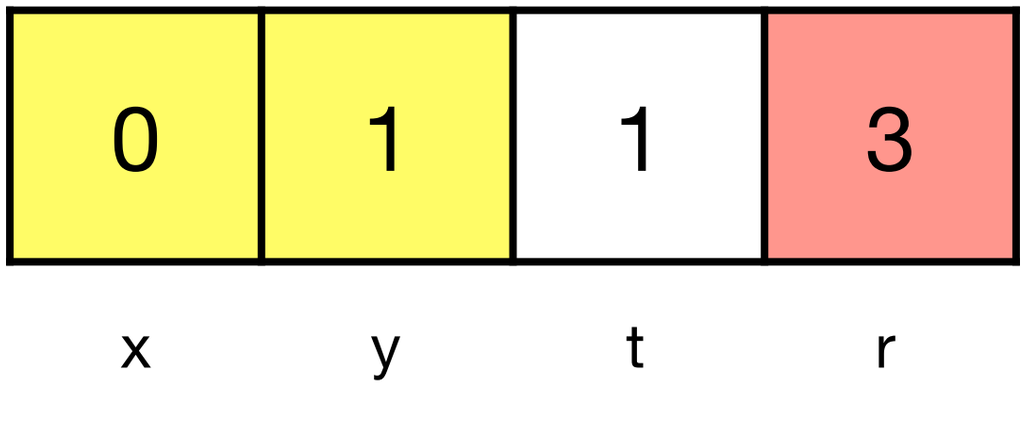
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
👉 4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



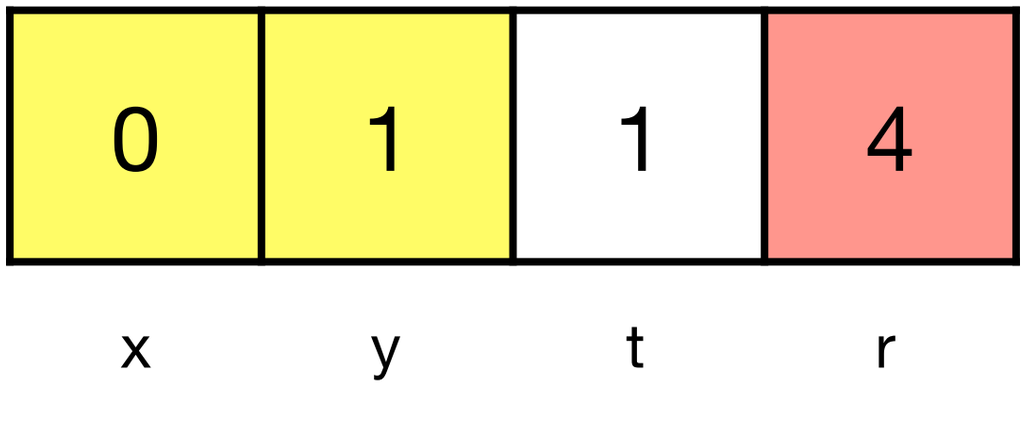
1: dec(y), 2, 7
👉 2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



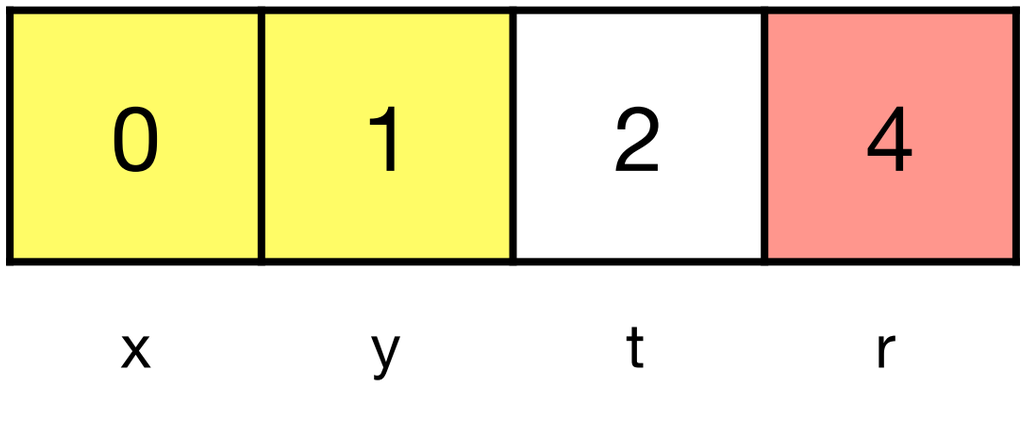
1: dec(y), 2, 7
2: dec(x), 3, 5
👉 3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



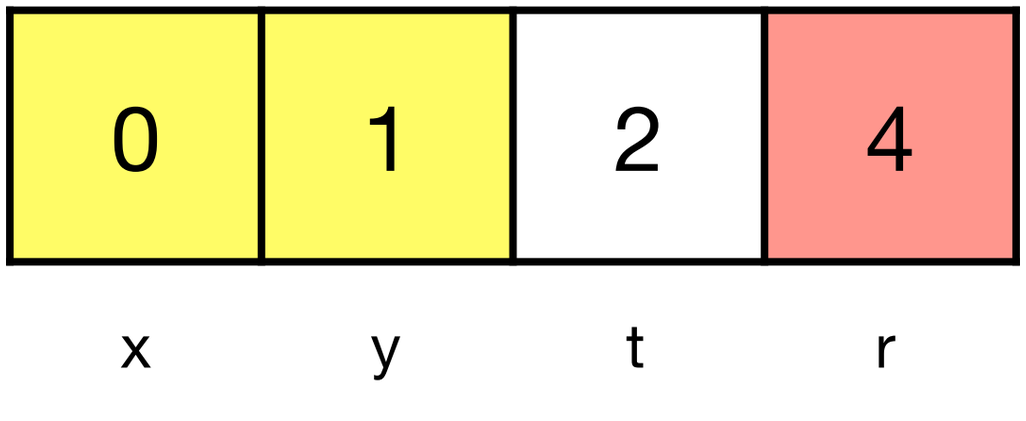
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
👉 4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



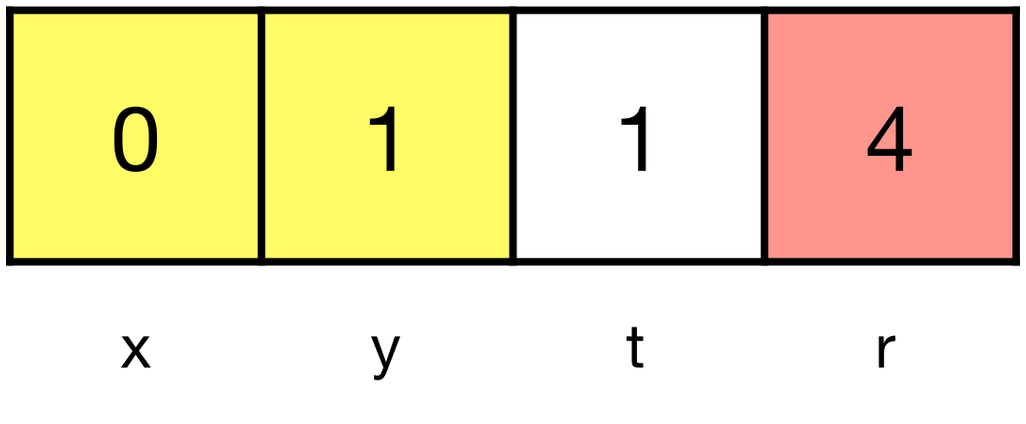
1: dec(y), 2, 7
👉 2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



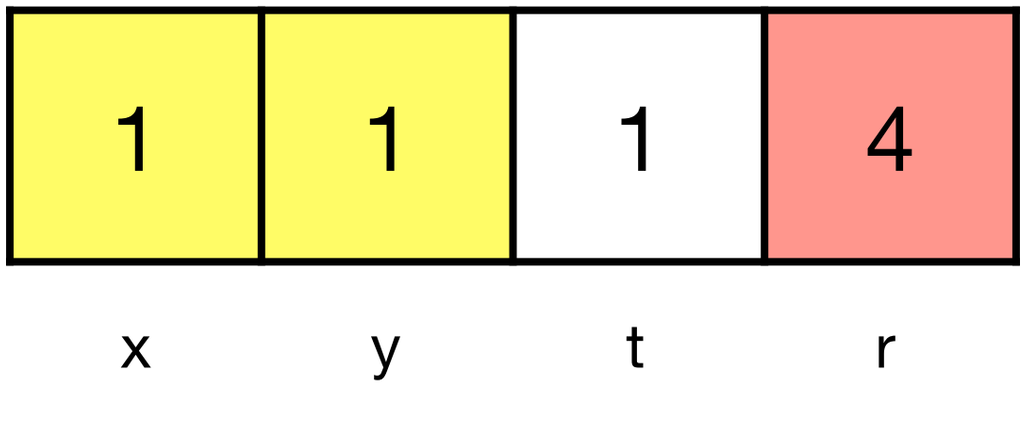
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



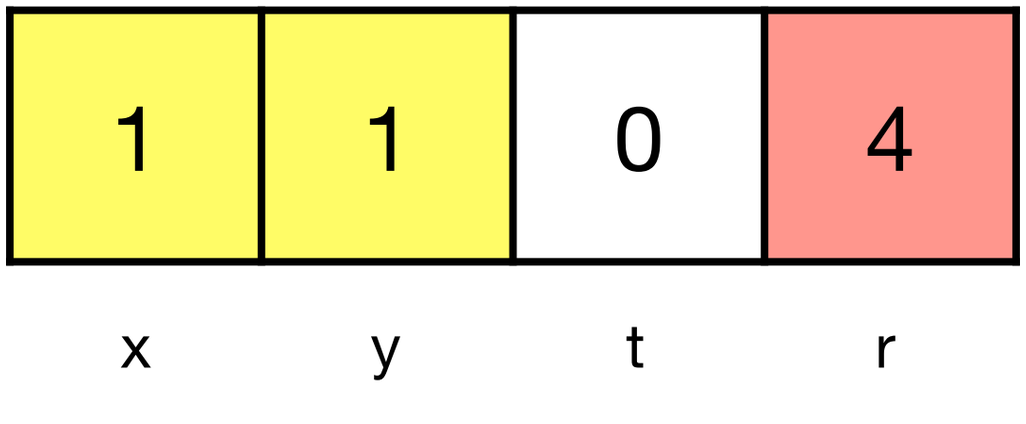
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
👉 6: inc(x), 5
7: stop

Machines à registres



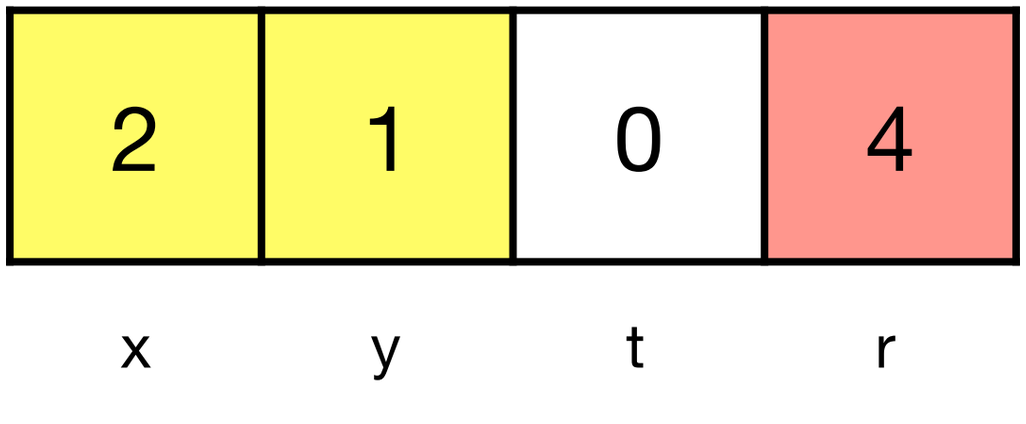
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



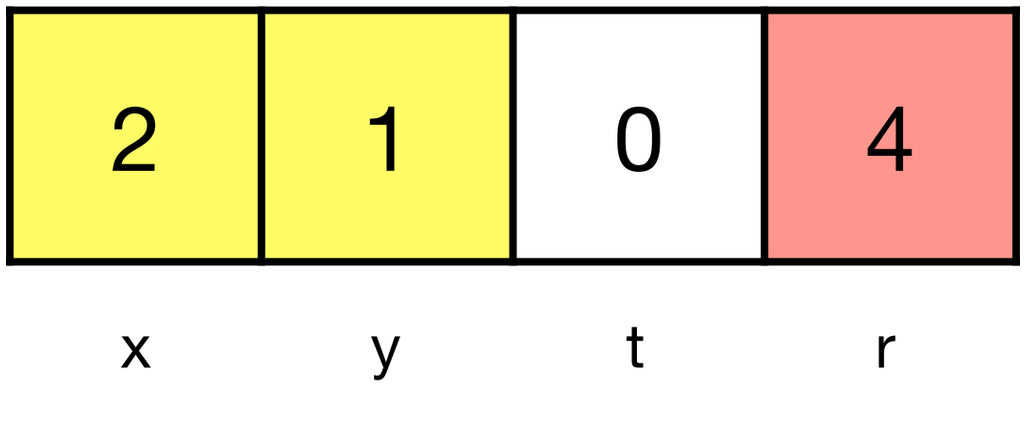
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
👉 6: inc(x), 5
7: stop

Machines à registres



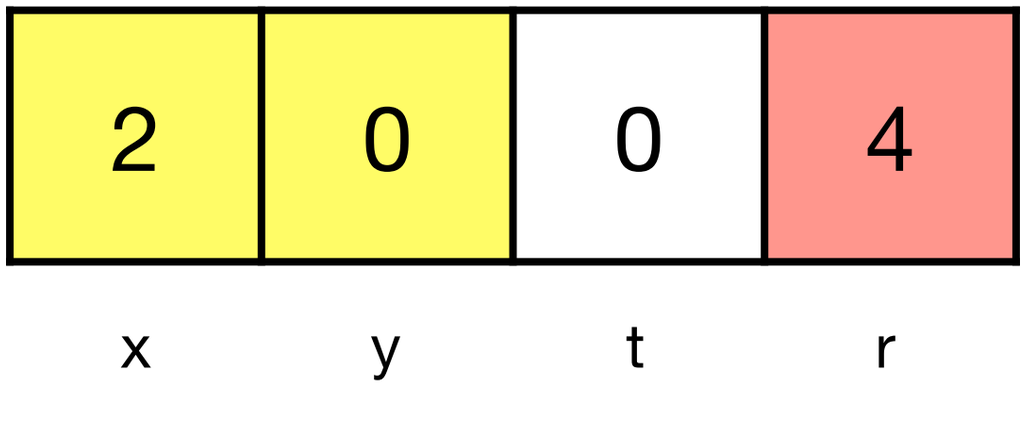
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



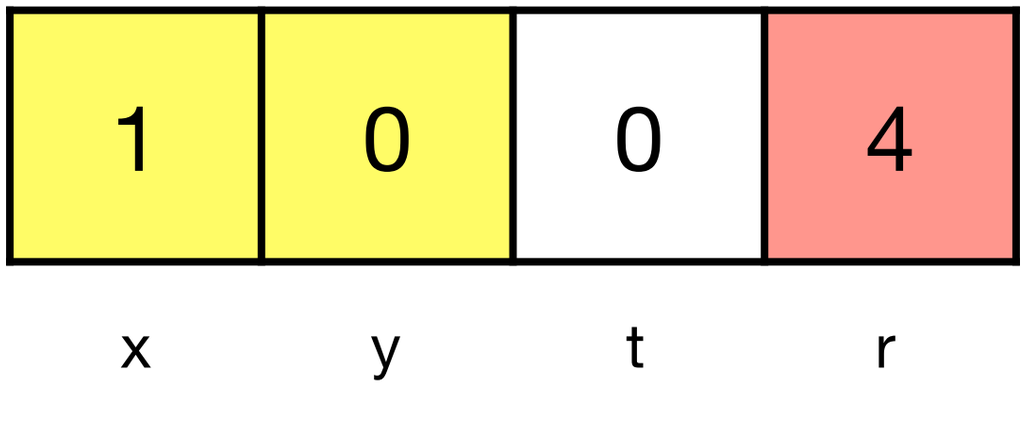
👉 1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



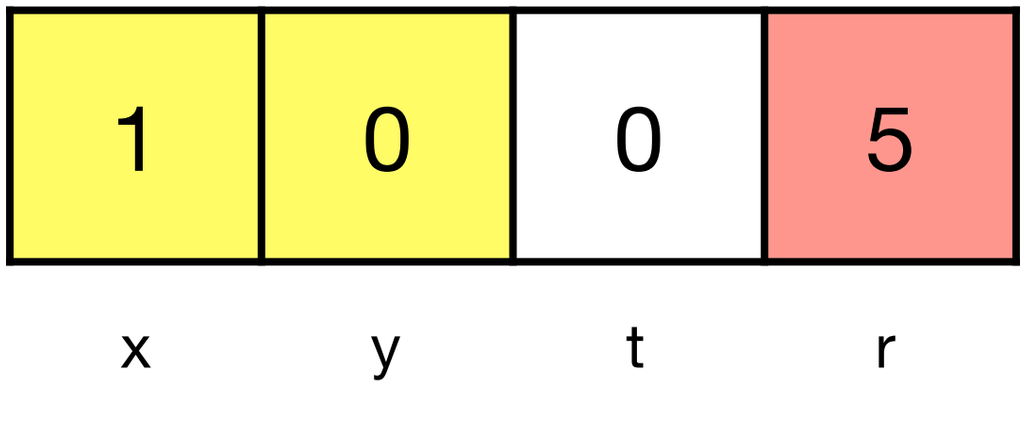
1: dec(y), 2, 7
👉 2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



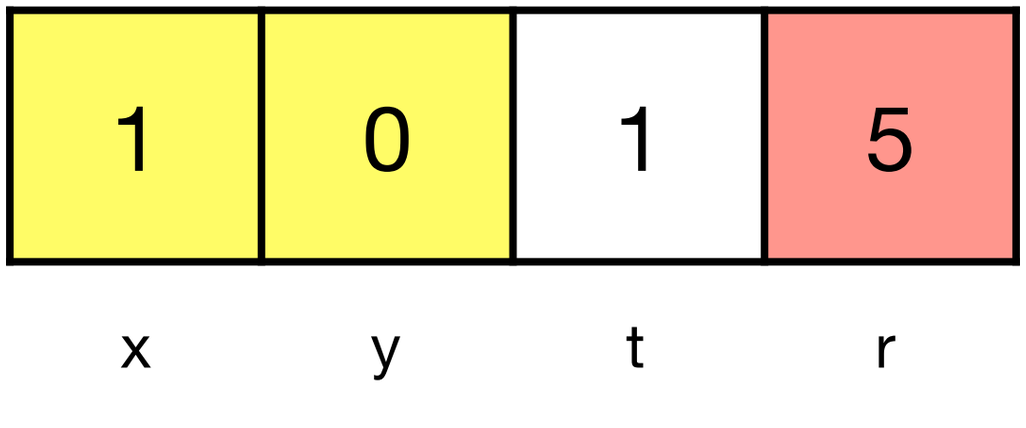
1: dec(y), 2, 7
2: dec(x), 3, 5
👉 3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



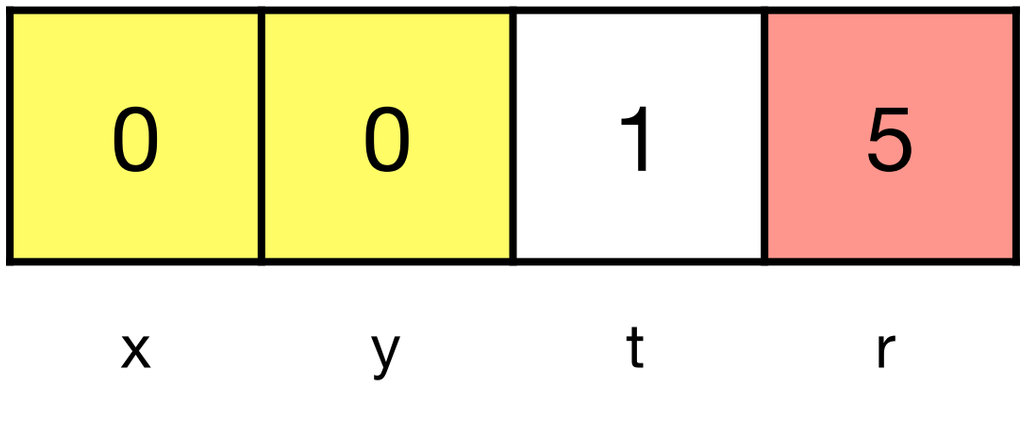
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
👉 4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



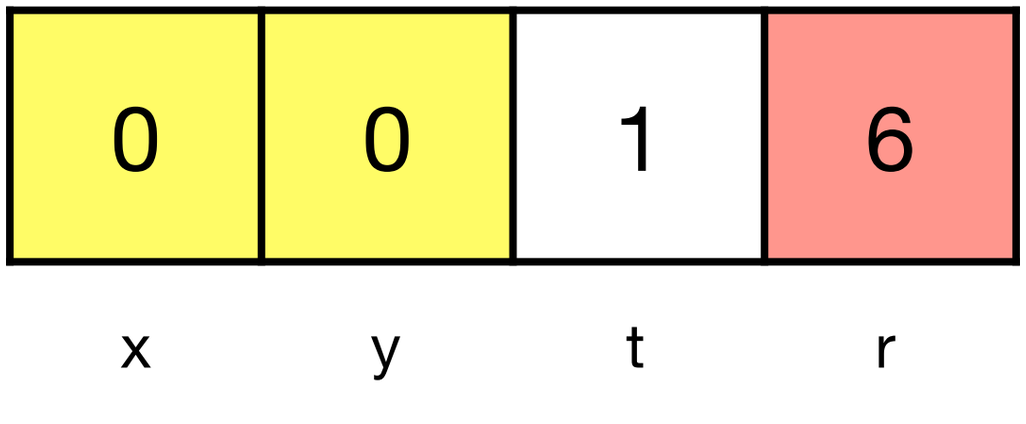
1: dec(y), 2, 7
👉 2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



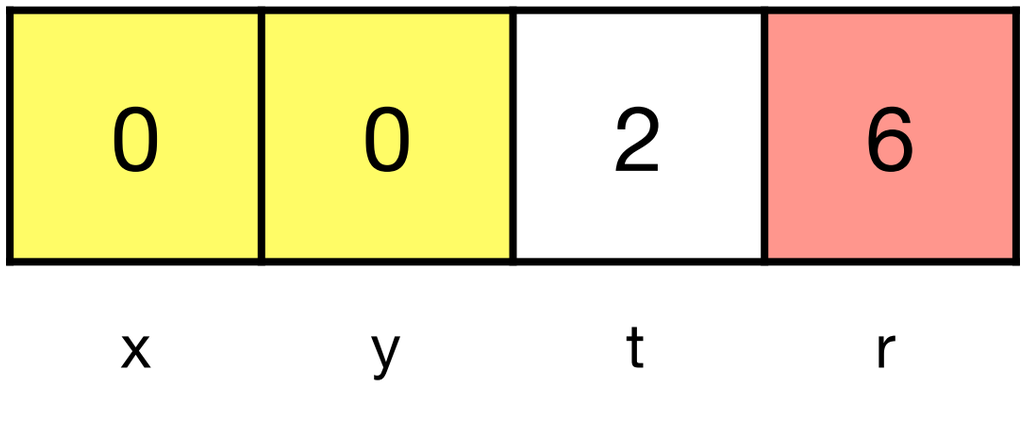
1: dec(y), 2, 7
2: dec(x), 3, 5
👉 3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



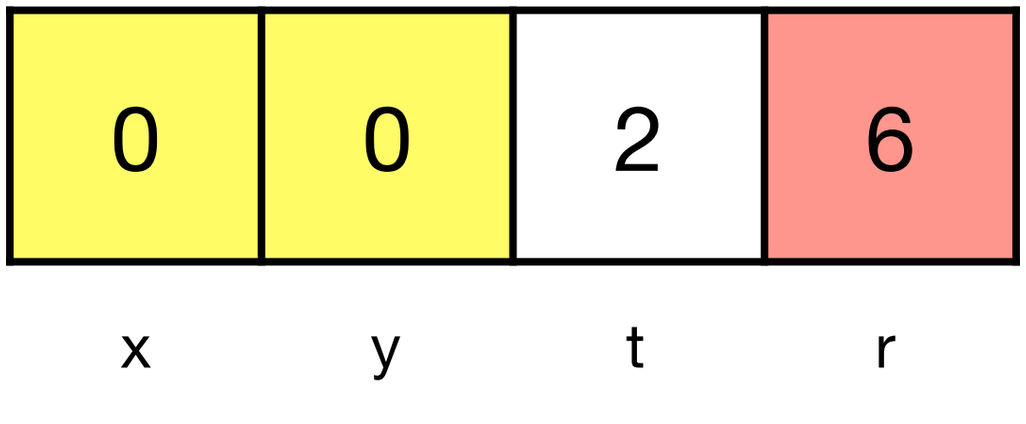
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
👉 4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



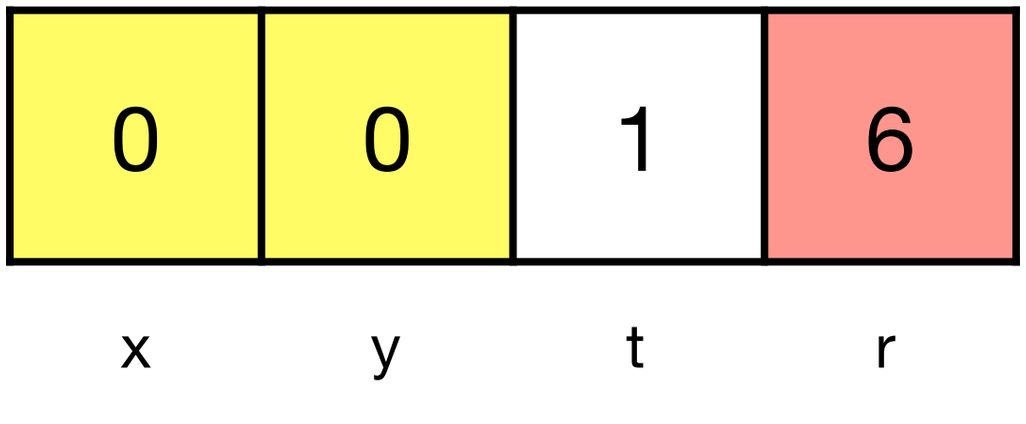
1: dec(y), 2, 7
👉 2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



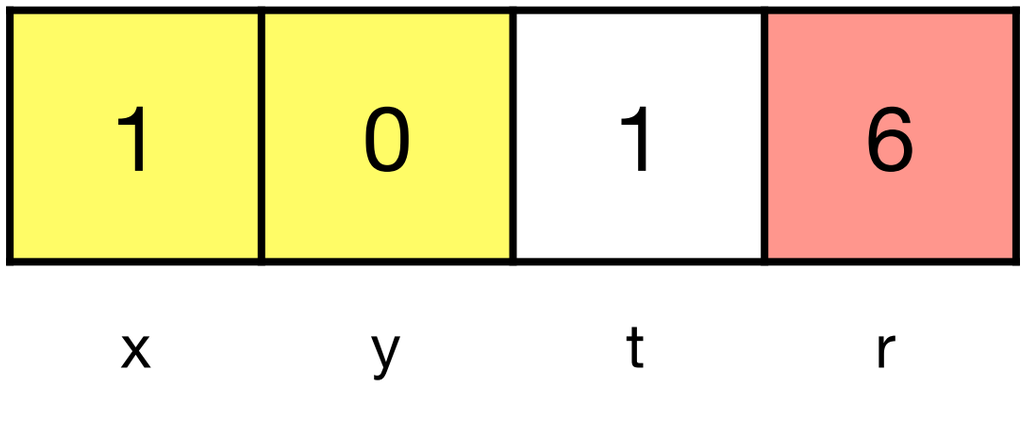
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



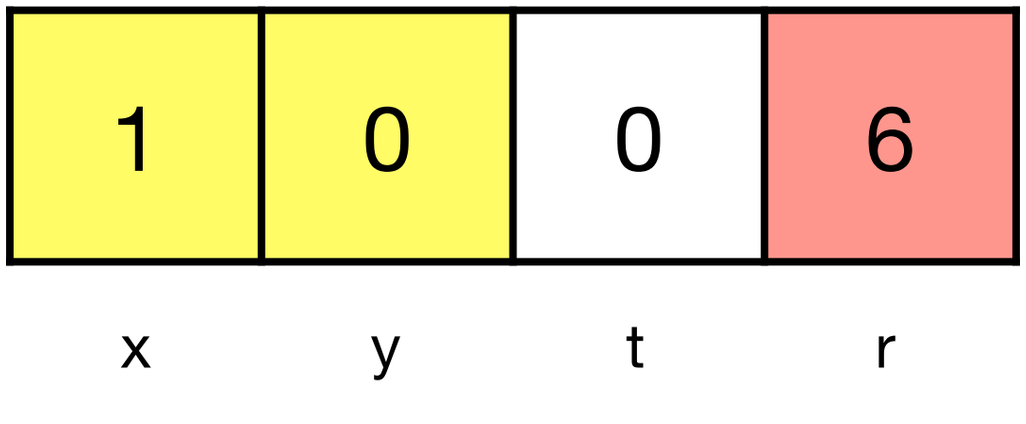
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
👉 6: inc(x), 5
7: stop

Machines à registres



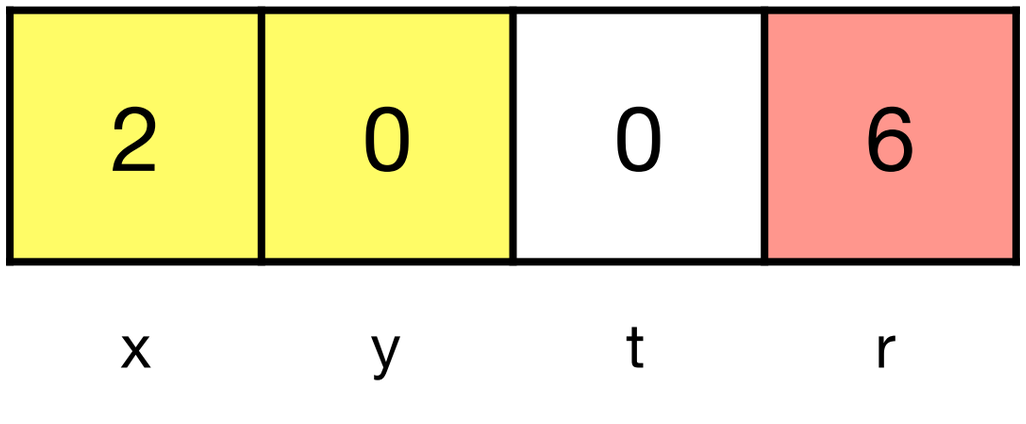
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



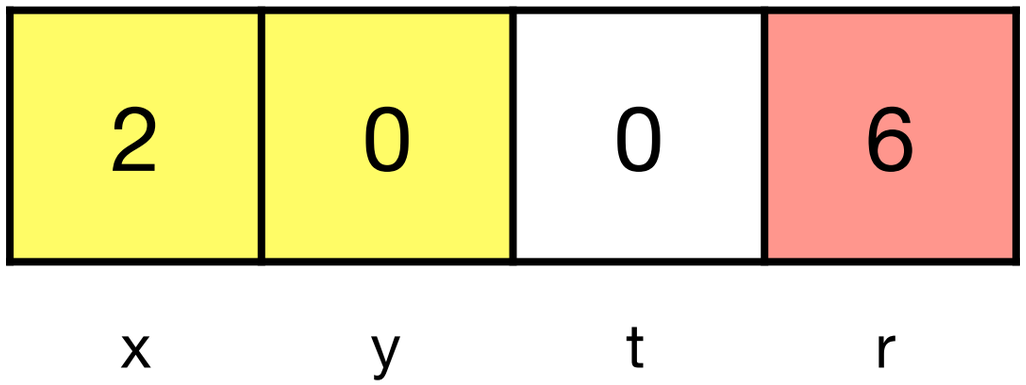
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
👉 6: inc(x), 5
7: stop

Machines à registres



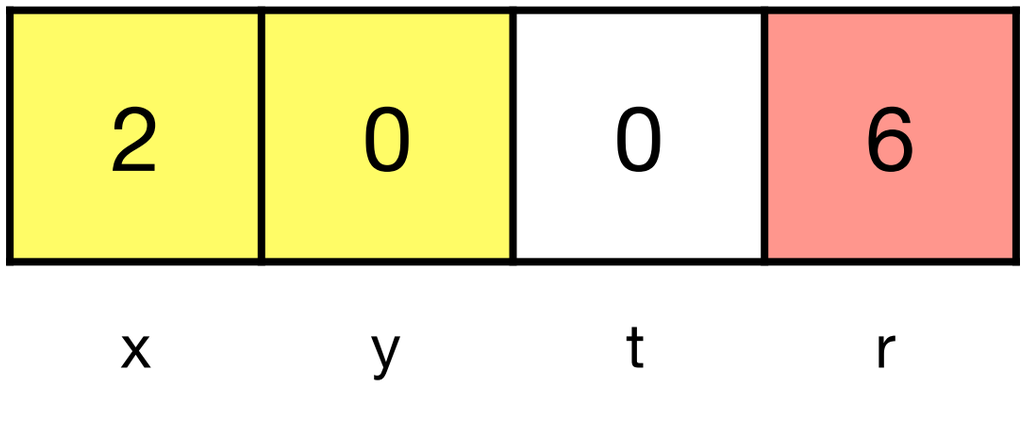
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



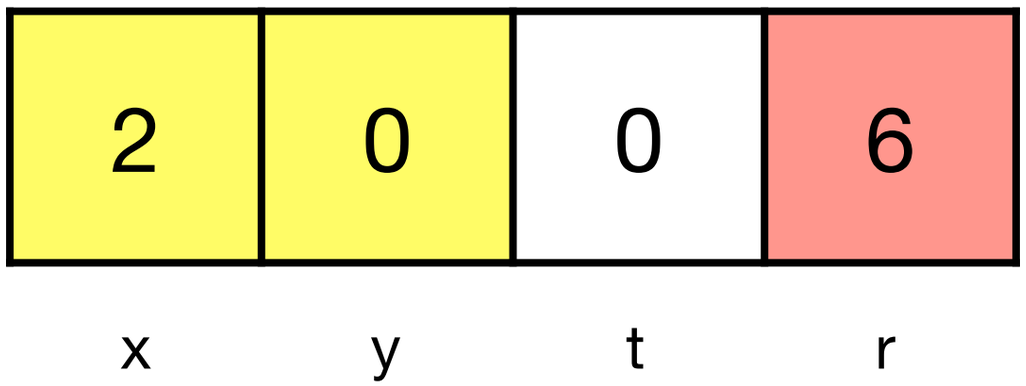
👉 1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
7: stop

Machines à registres



1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
👉 7: stop

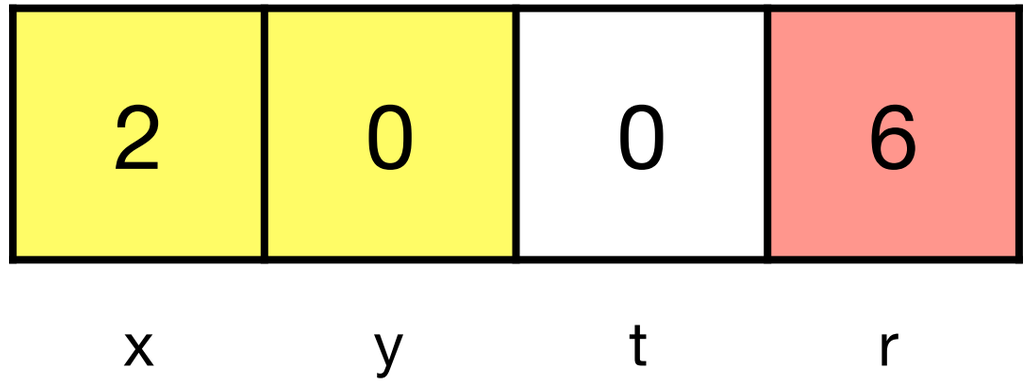
Machines à registres



1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
👉 7: stop

qu’est-ce qu’on a calculé ?

Machines à registres



1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
6: inc(x), 5
👉 7: stop

le produit des valeurs initiales de x et y

Exercice 5 du TD8

La machine à registres peut simuler n'importe quel algorithme en Python !

Pseudo-code / Python

itérations

```
Pour .. de .. à .. faire
   ..
FinPour

Tant que .. faire
   ..
FinTantQue
```

fonctions

```
fonction abc(arguments) :
   ..
   retourner(..)
```

conditionnelles

```
Si .. alors
   ..
FinSi

Si .. alors
   ..
Sinon
   ..
FinSi
```

écriture/lecture

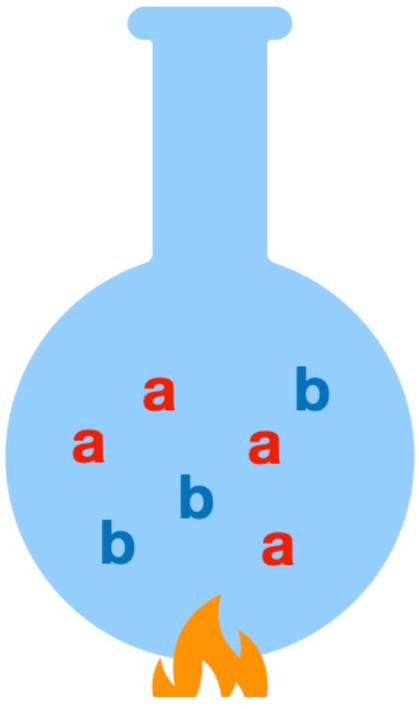
```
écrire(« .. »)
réponse := lire()
```

variables

```
x := 3
y := 2
x := x+y
```

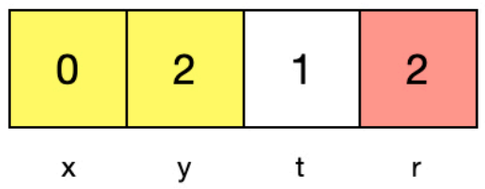
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
👉 6: inc(x), 5
7: stop

Simuler une machine à registres avec la chimie



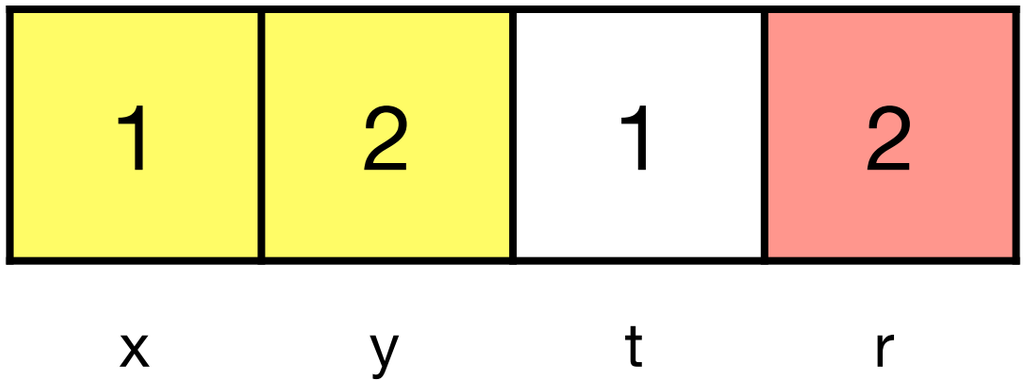
a → c

b → c



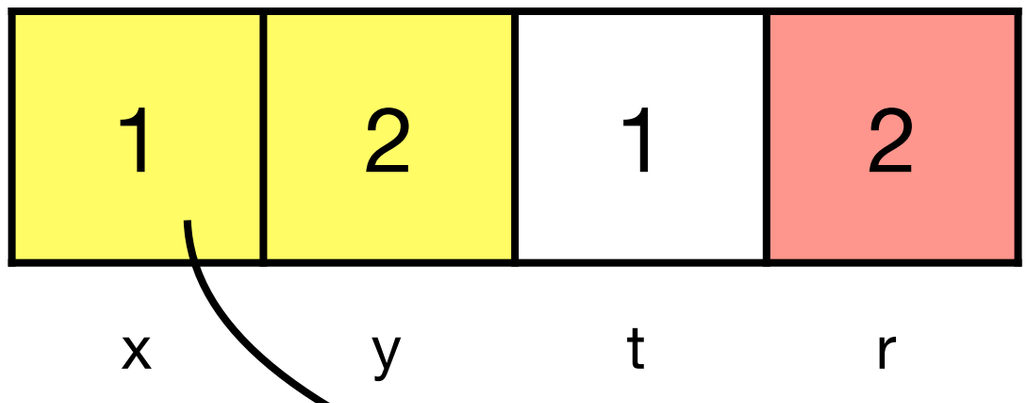
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
👉 6: inc(x), 5
7: stop

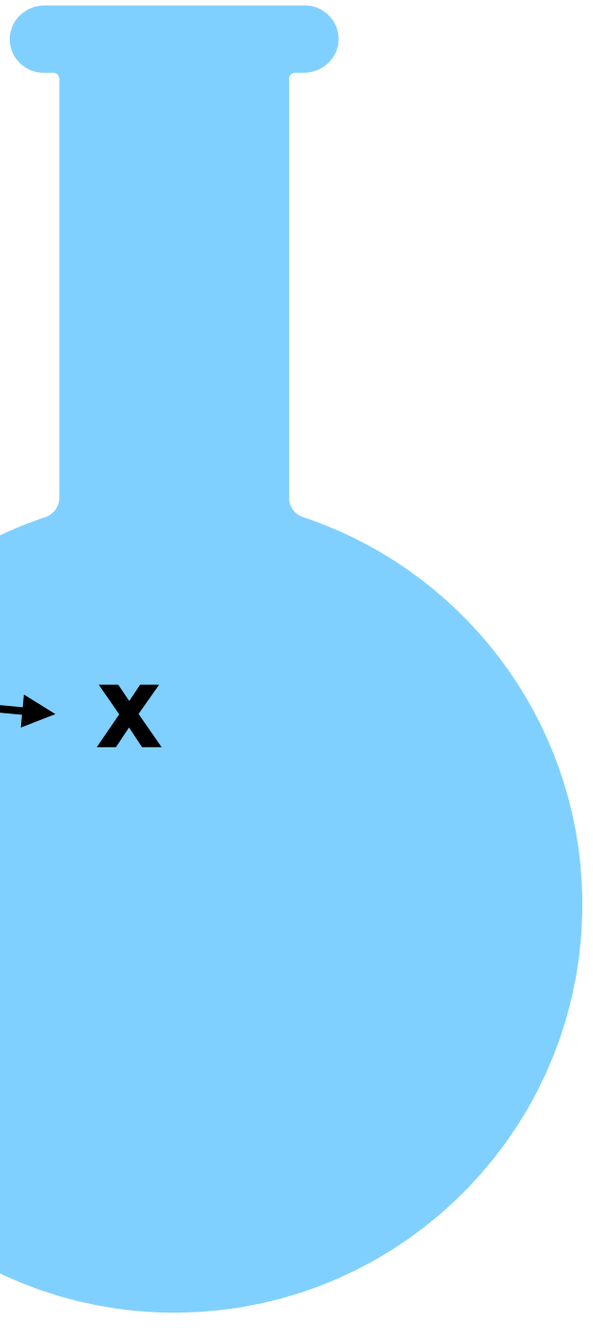
Config. machine → ballon



1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop

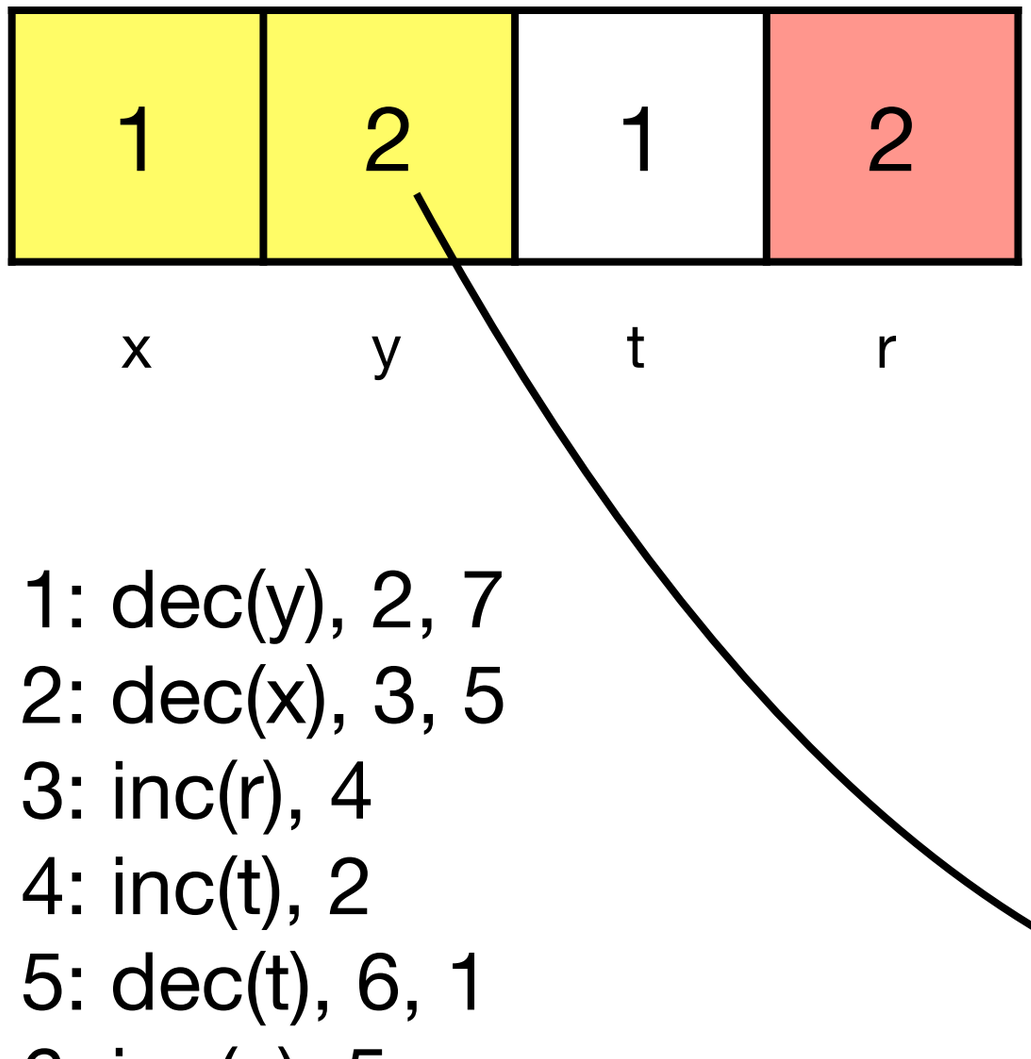
Config. machine → ballon



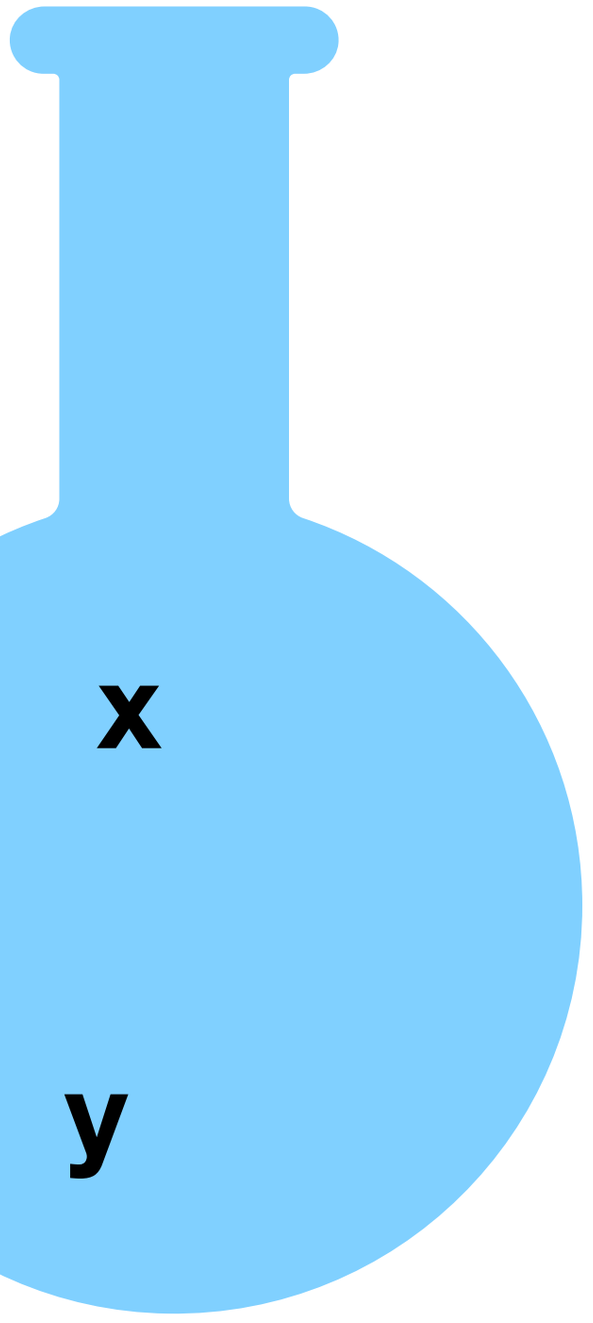


1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop

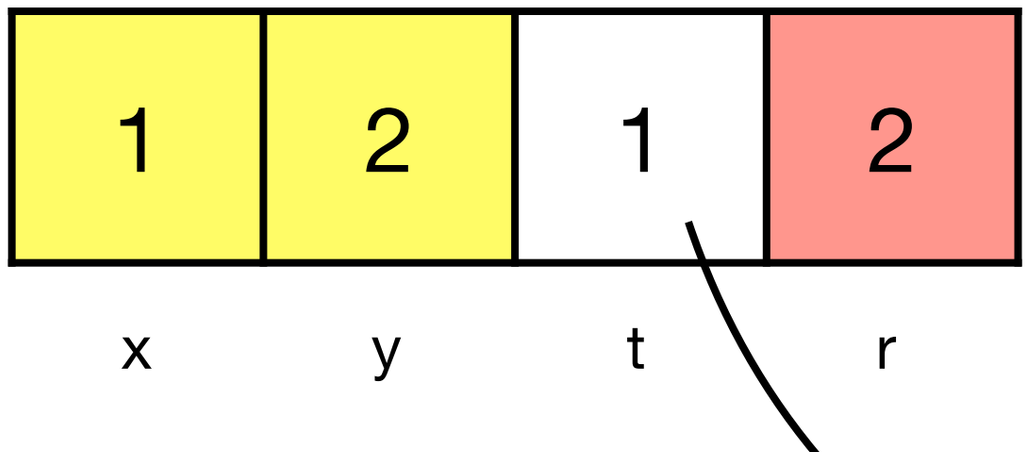
Config. machine → ballon



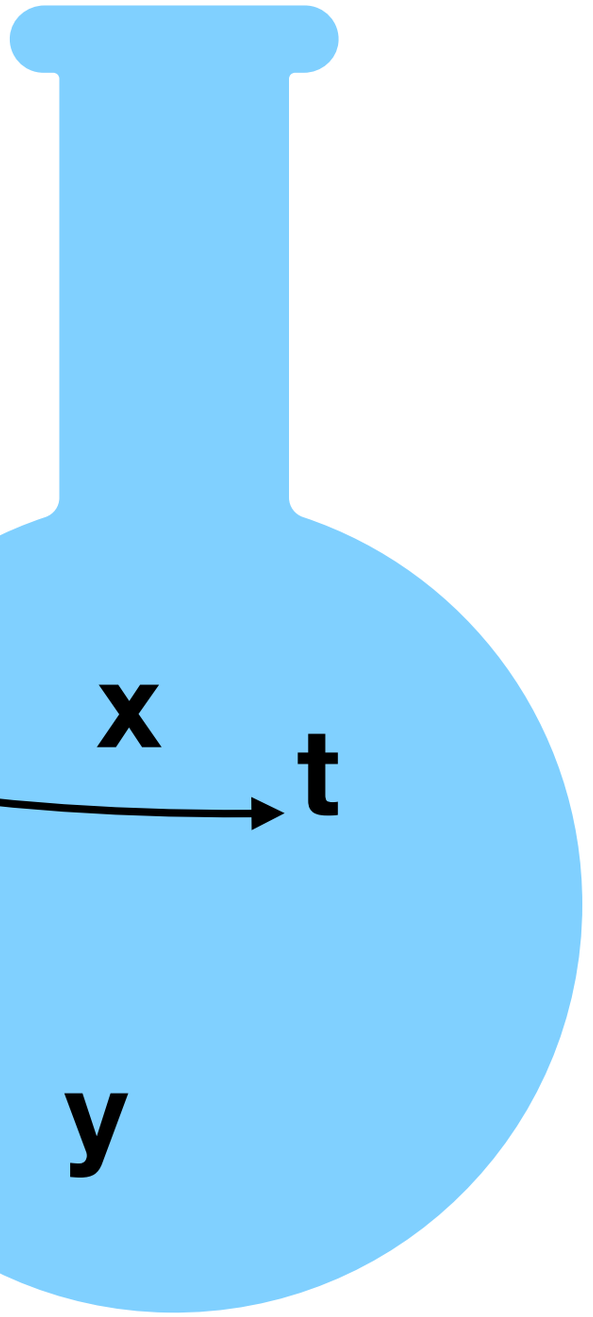
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop



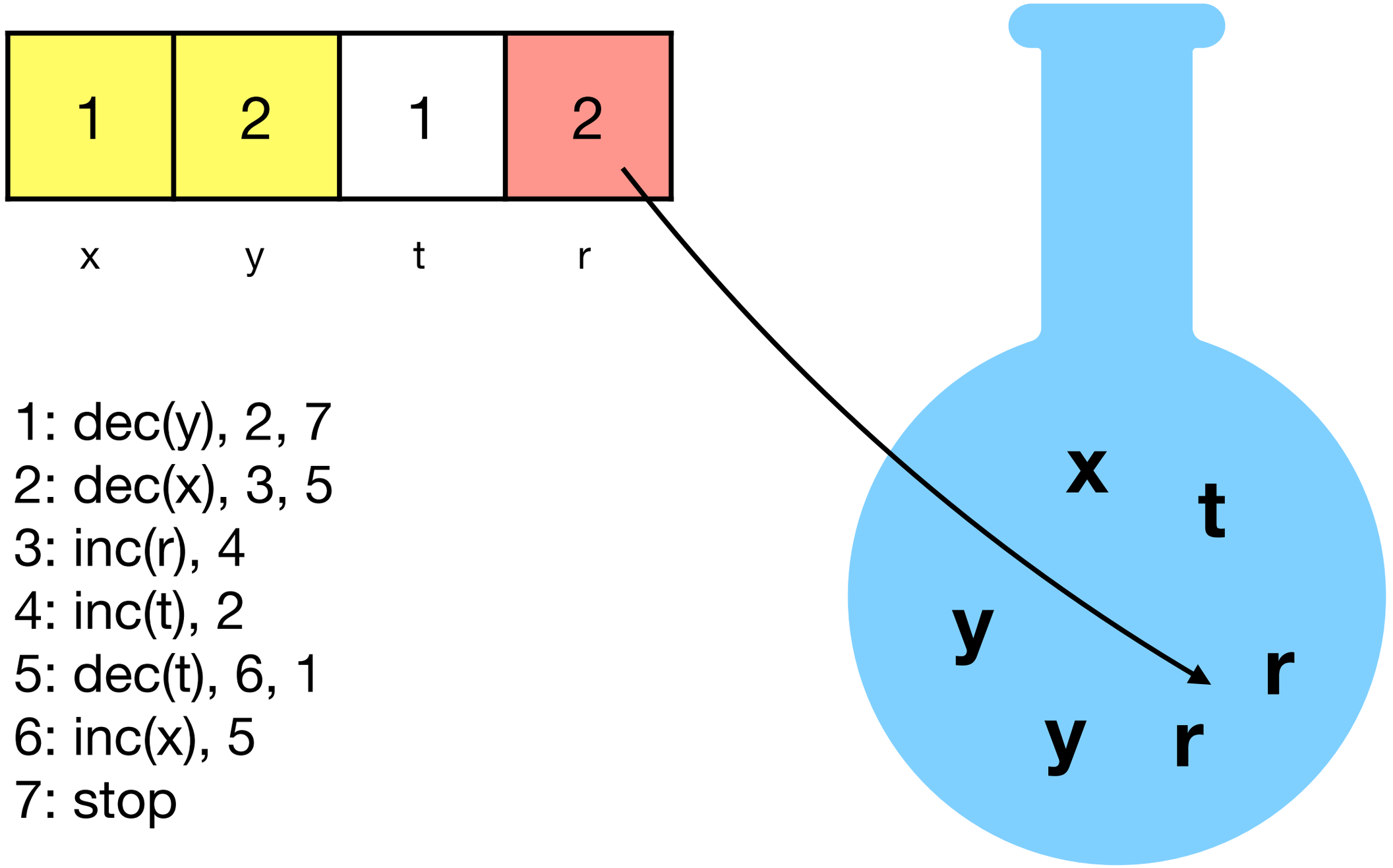
Config. machine → ballon



1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop

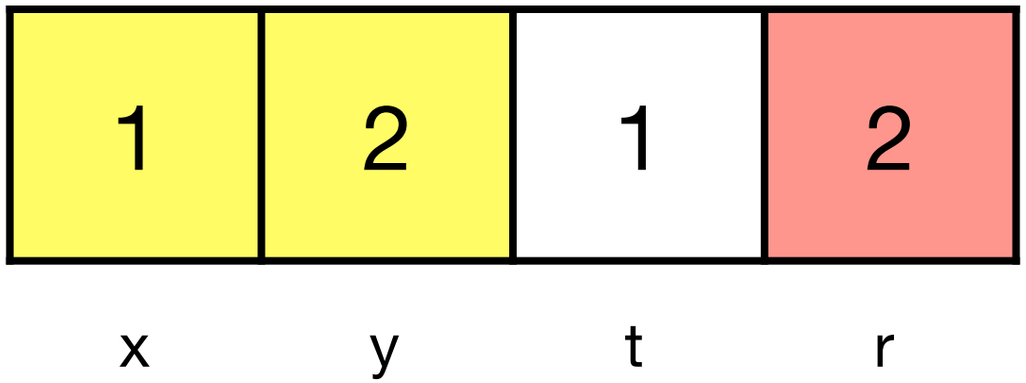


Config. machine → ballon

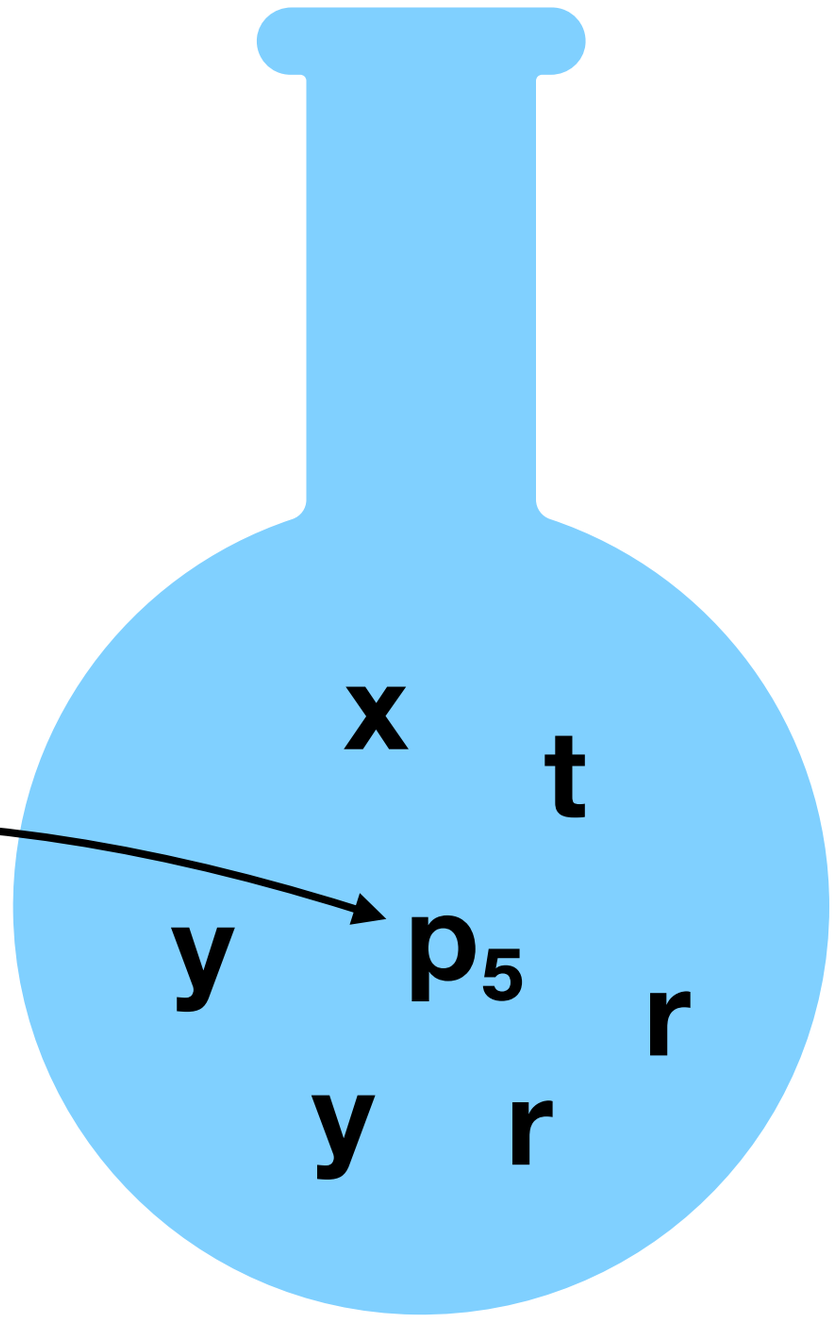


1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop

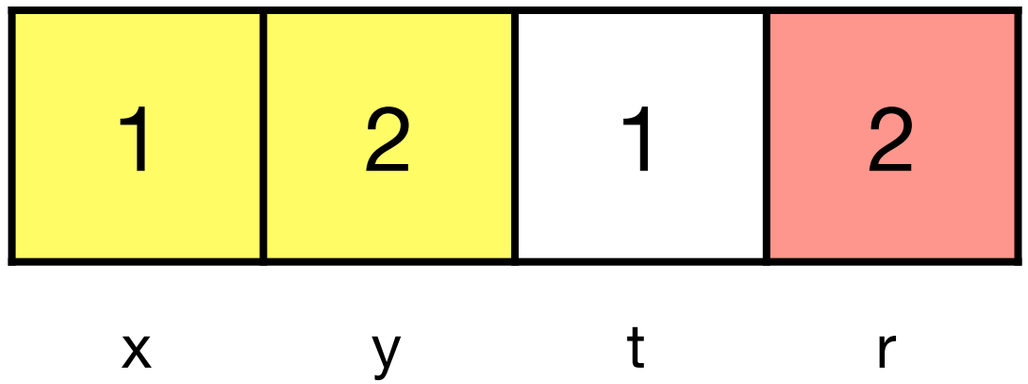
Config. machine → ballon



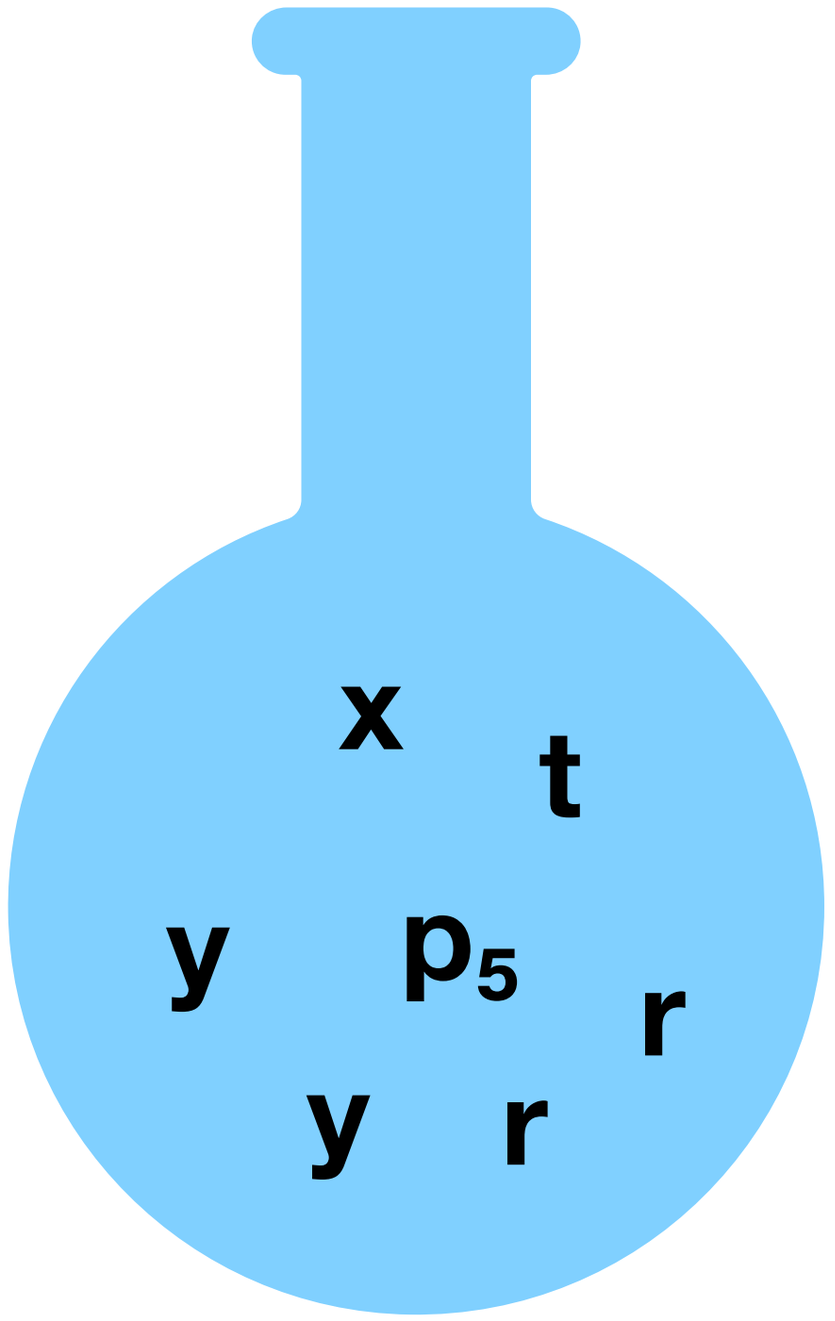
1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop



Config. machine → ballon



1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
👉 5: dec(t), 6, 1
6: inc(x), 5
7: stop



Instructions → réactions

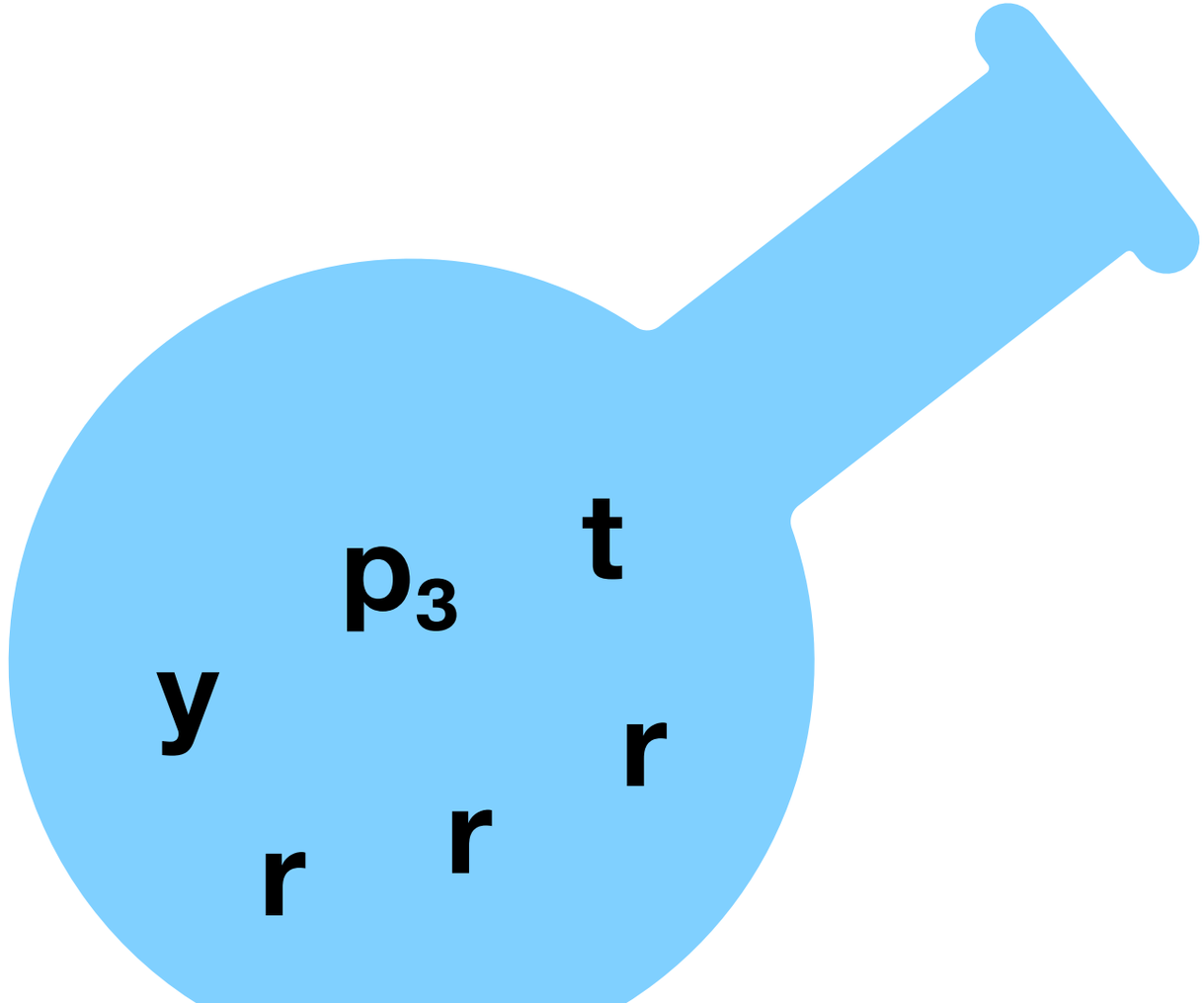
3: inc(r), 4

Instructions → réactions

3: inc(r), 4 $p_3 \rightarrow p_4 + r$

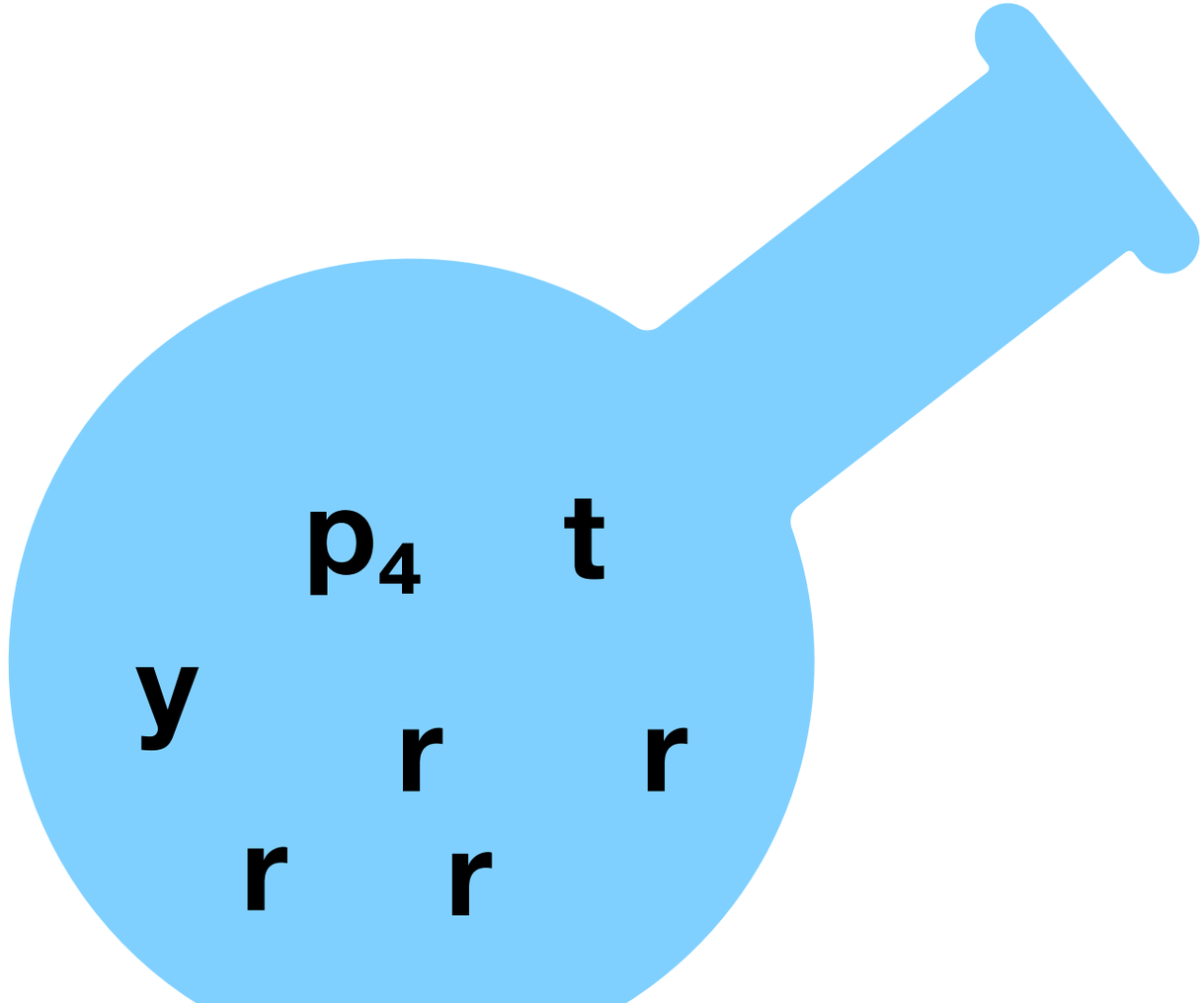
Instructions → réactions

3: inc(r), 4 $p_3 \rightarrow p_4 + r$



Instructions → réactions

3: inc(r), 4 $p_3 \rightarrow p_4 + r$



Instructions → réactions

5: dec(t), 6, 1

Instructions → réactions

5: dec(t), 6, 1

$p_5 \rightarrow p_5' + \bar{t}$

$\bar{t} + t \rightarrow t'$

$p_5' \rightarrow p_5''$

$p_5'' + t' \rightarrow p_6$

$p_5'' + \bar{t} \rightarrow p_1$

Instructions → réactions

5: dec(t), 6, 1

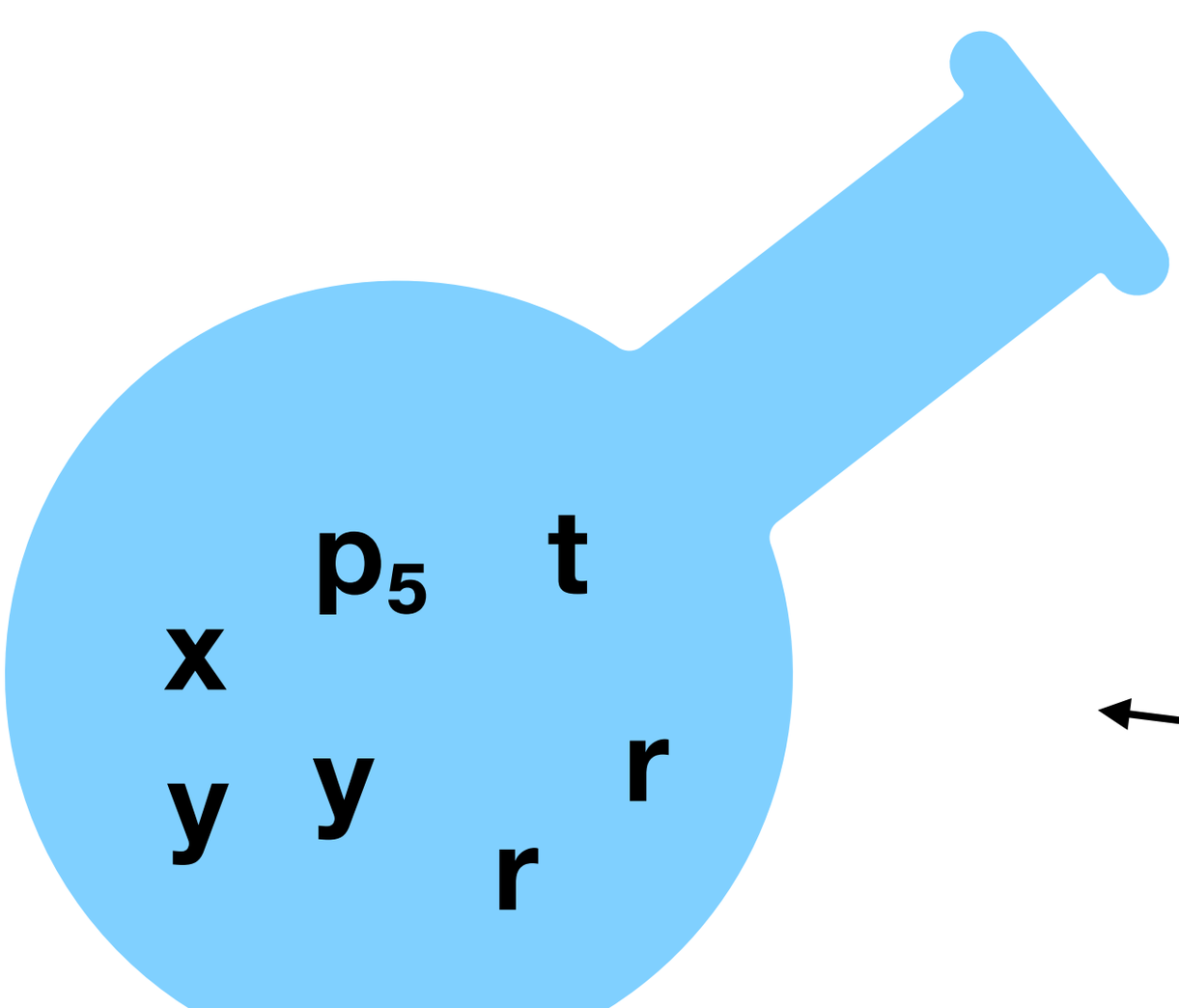
$p_5 \rightarrow p_5' + \bar{t}$

$\bar{t} + t \rightarrow t'$

$p_5' \rightarrow p_5''$

$p_5'' + t' \rightarrow p_6$

$p_5'' + \bar{t} \rightarrow p_1$



s'il y a au moins un t

Instructions → réactions

5: dec(t), 6, 1

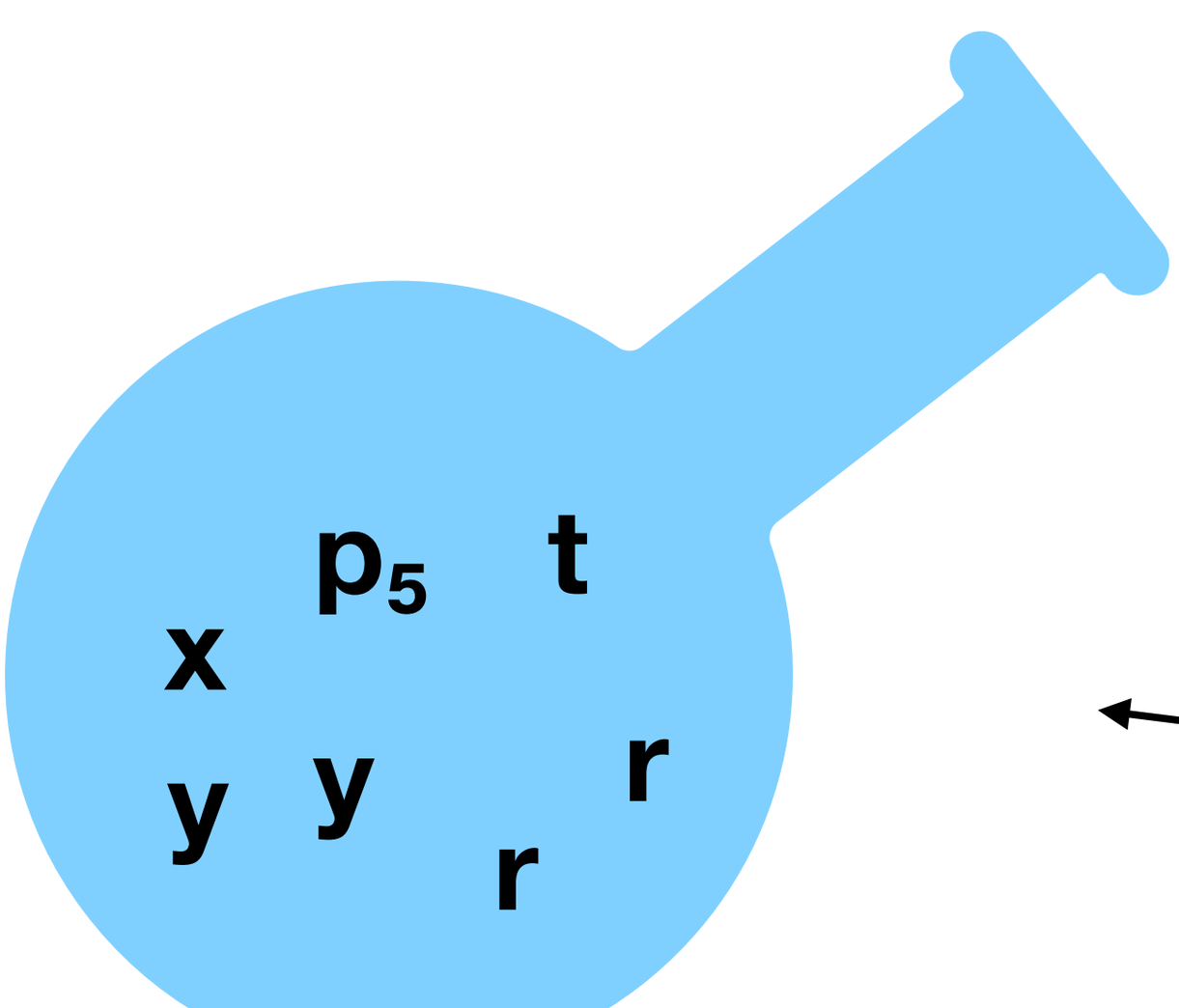
👉 $p_5 \rightarrow p_5' + \bar{t}$

$\bar{t} + t \rightarrow t'$

$p_5' \rightarrow p_5''$

$p_5'' + t' \rightarrow p_6$

$p_5'' + \bar{t} \rightarrow p_1$



s'il y a au moins un t

Instructions → réactions

5: dec(t), 6, 1

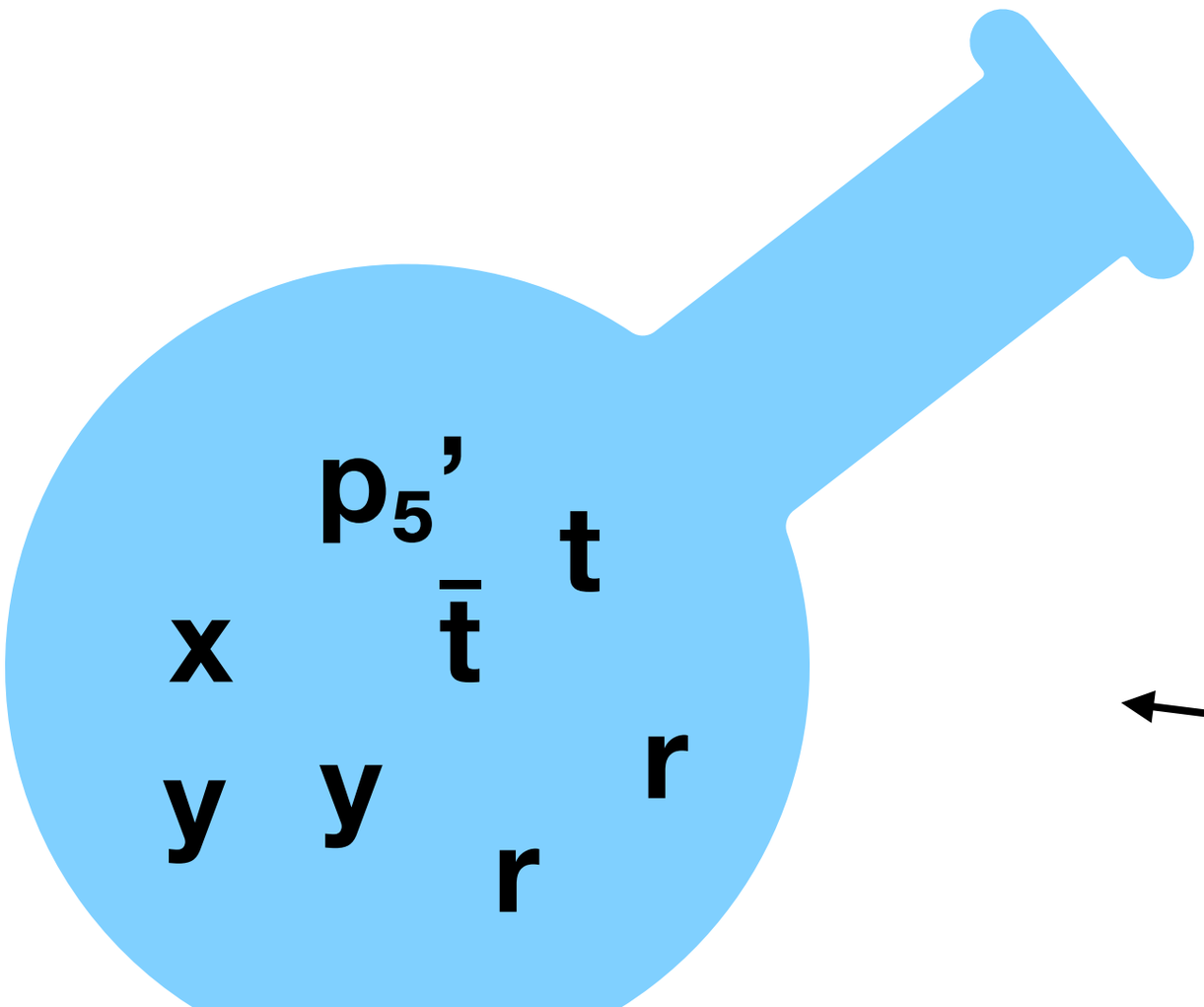
$p_5 \rightarrow p_5' + \bar{t}$

👉 $\bar{t} + t \rightarrow t'$

👉 $p_5' \rightarrow p_5''$

$p_5'' + t' \rightarrow p_6$

$p_5'' + \bar{t} \rightarrow p_1$



s'il y a au moins un t

Instructions → réactions

5: dec(t), 6, 1

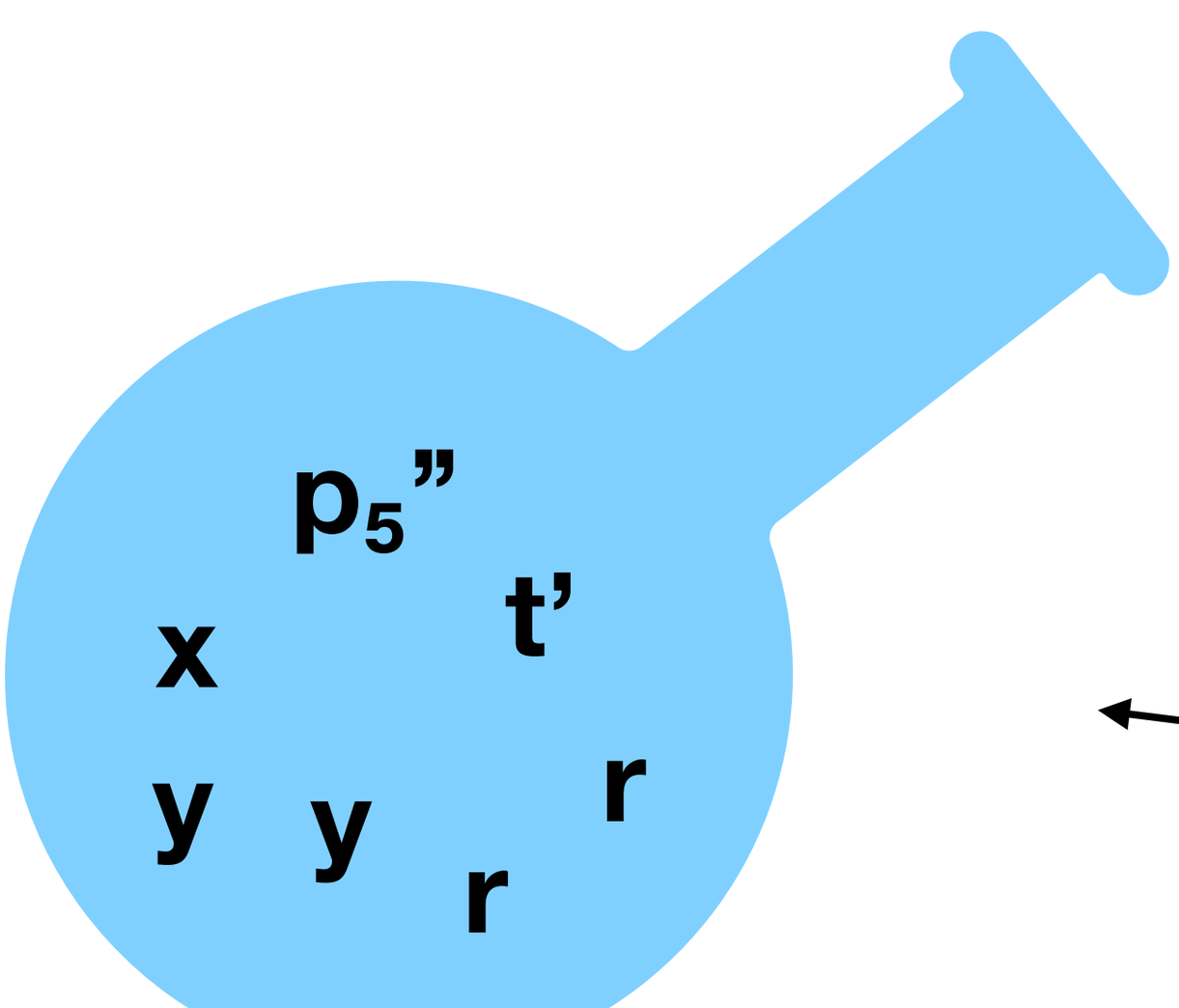
$p_5 \rightarrow p_5' + \bar{t}$

$\bar{t} + t \rightarrow t'$

$p_5' \rightarrow p_5''$

👉 $p_5'' + t' \rightarrow p_6$

$p_5'' + \bar{t} \rightarrow p_1$



s’il y a au moins un t

Instructions → réactions

5: dec(t), 6, 1

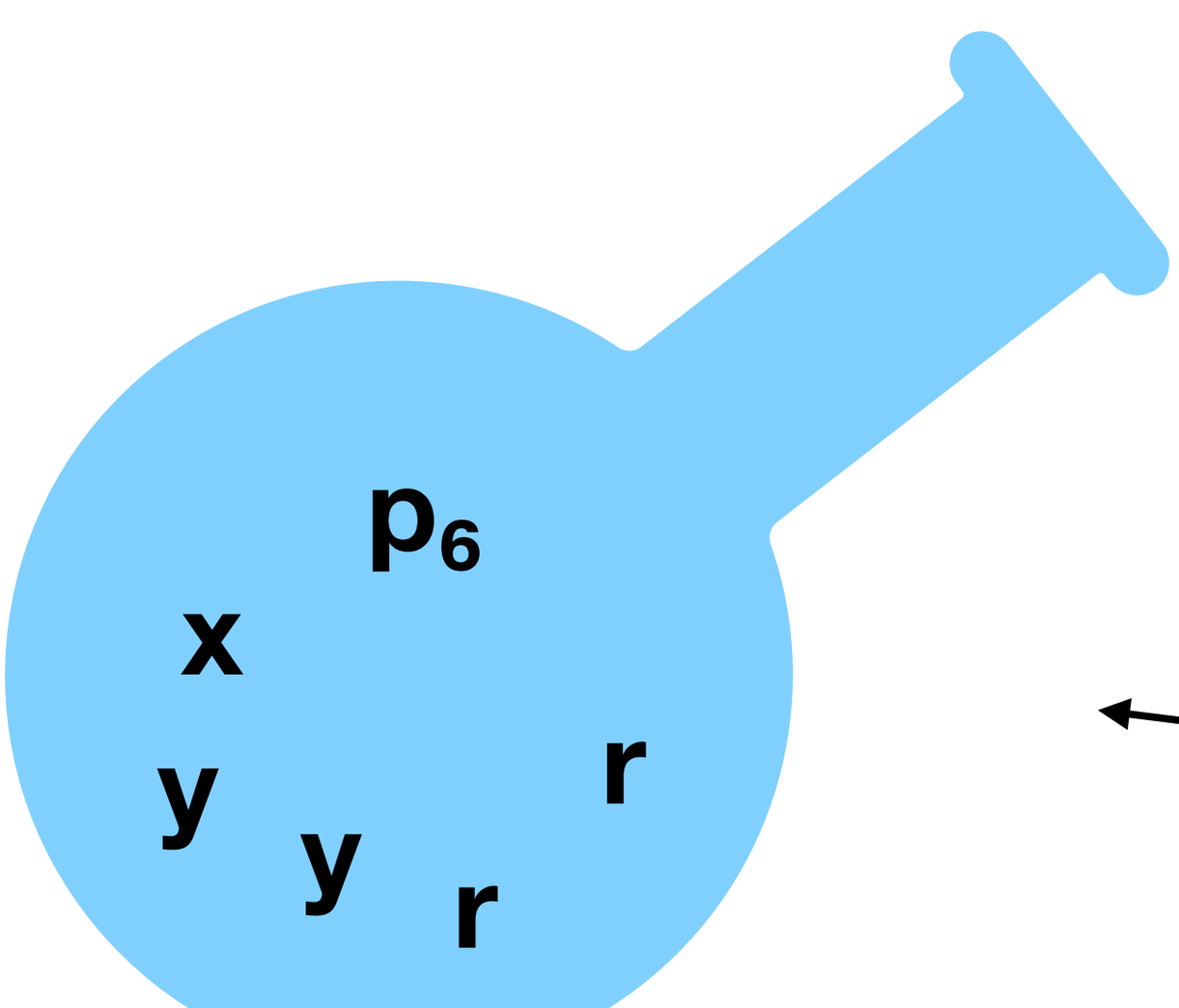
$p_5 \rightarrow p_5' + \bar{t}$

$\bar{t} + t \rightarrow t'$

$p_5' \rightarrow p_5''$

$p_5'' + t' \rightarrow p_6$

$p_5'' + \bar{t} \rightarrow p_1$



s'il y a au moins un t

Instructions → réactions

5: dec(t), 6, 1

$p_5 \rightarrow p_5' + \bar{t}$

$\bar{t} + t \rightarrow t'$

$p_5' \rightarrow p_5''$

$p_5'' + t' \rightarrow p_6$

$p_5'' + \bar{t} \rightarrow p_1$

Instructions → réactions

5: dec(t), 6, 1

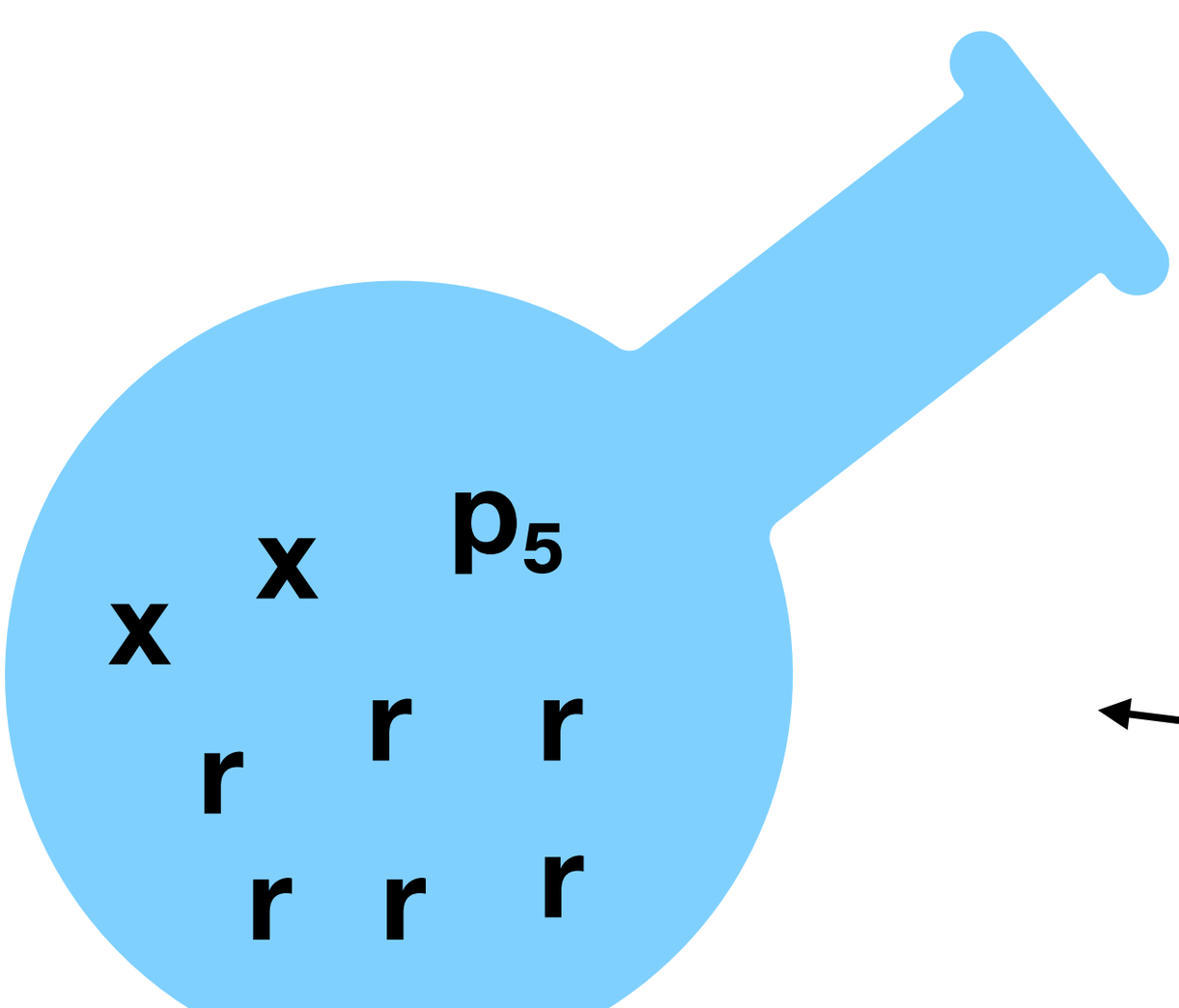
$p_5 \rightarrow p_5' + \bar{t}$

$\bar{t} + t \rightarrow t'$

$p_5' \rightarrow p_5''$

$p_5'' + t' \rightarrow p_6$

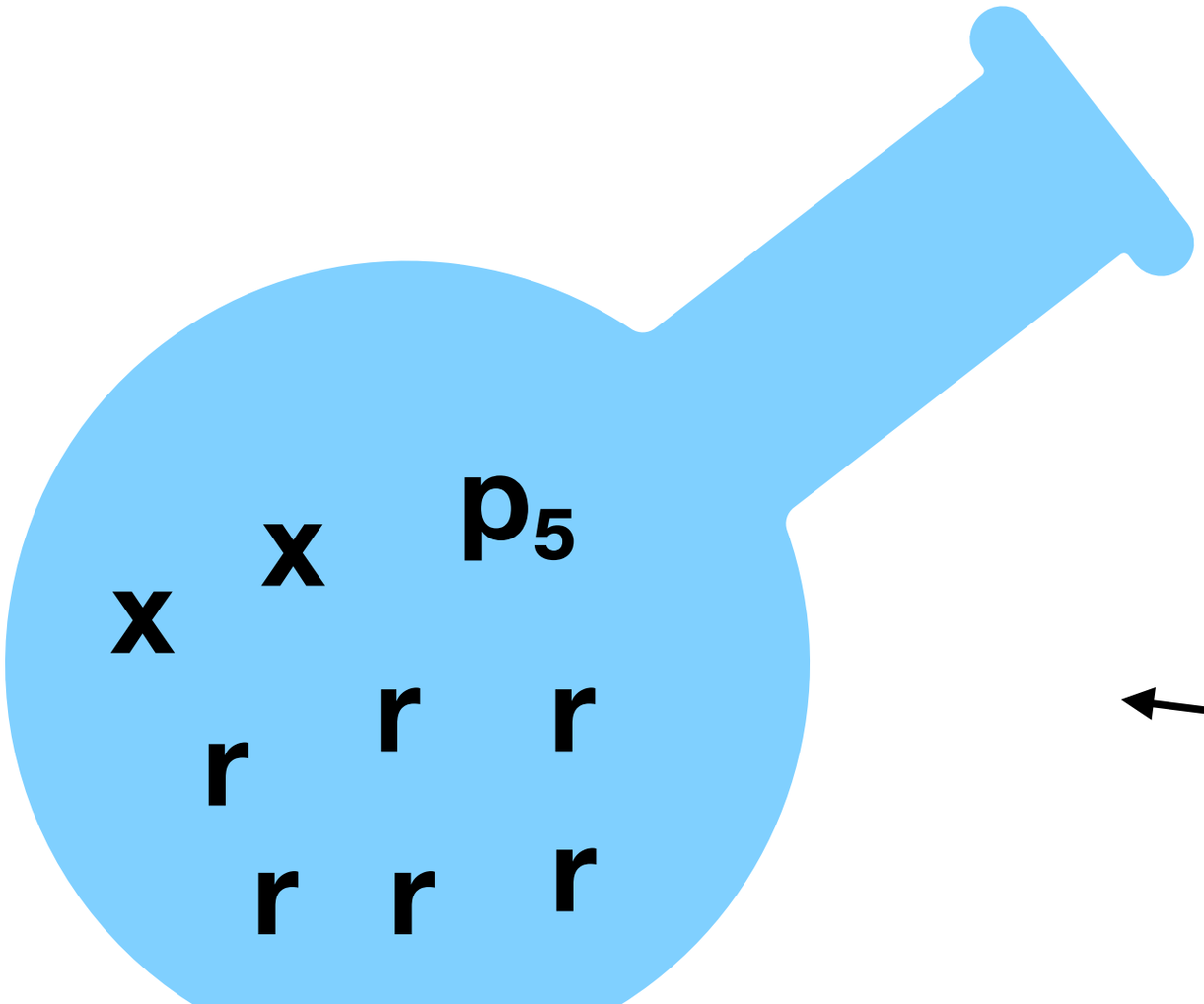
$p_5'' + \bar{t} \rightarrow p_1$



s'il n'y a pas de t

Instructions → réactions

5: dec(t), 6, 1



👉 $p_5 \rightarrow p_5' + \bar{t}$

$\bar{t} + t \rightarrow t'$

$p_5' \rightarrow p_5''$

$p_5'' + t' \rightarrow p_6$

$p_5'' + \bar{t} \rightarrow p_1$

s'il n'y a pas de t

Instructions → réactions

5: dec(t), 6, 1

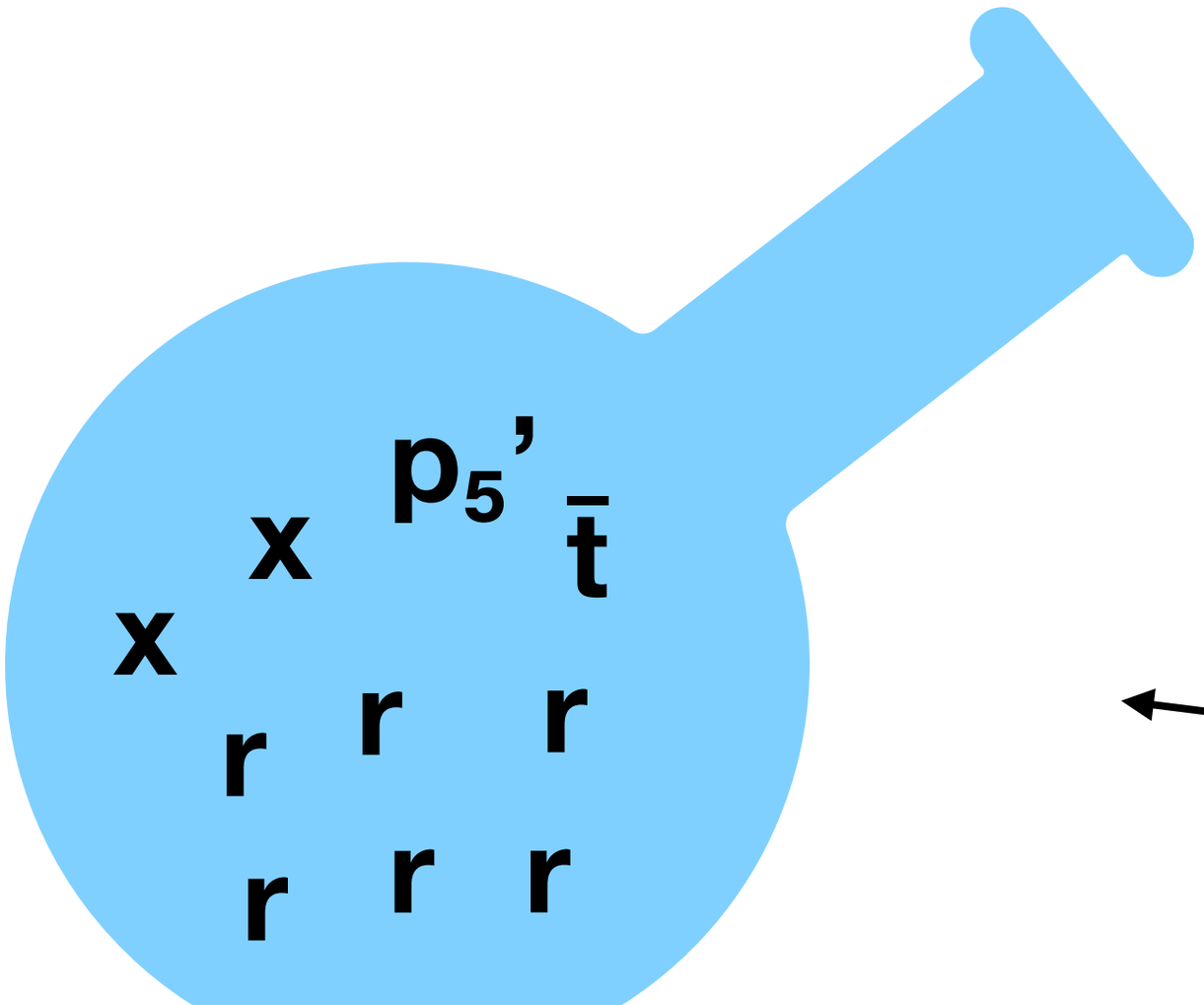
$p_5 \rightarrow p_5' + \bar{t}$

❌ $\bar{t} + t \rightarrow t'$

👉 $p_5' \rightarrow p_5''$

$p_5'' + t' \rightarrow p_6$

$p_5'' + \bar{t} \rightarrow p_1$



s'il n'y a pas de t

Instructions → réactions

5: dec(t), 6, 1

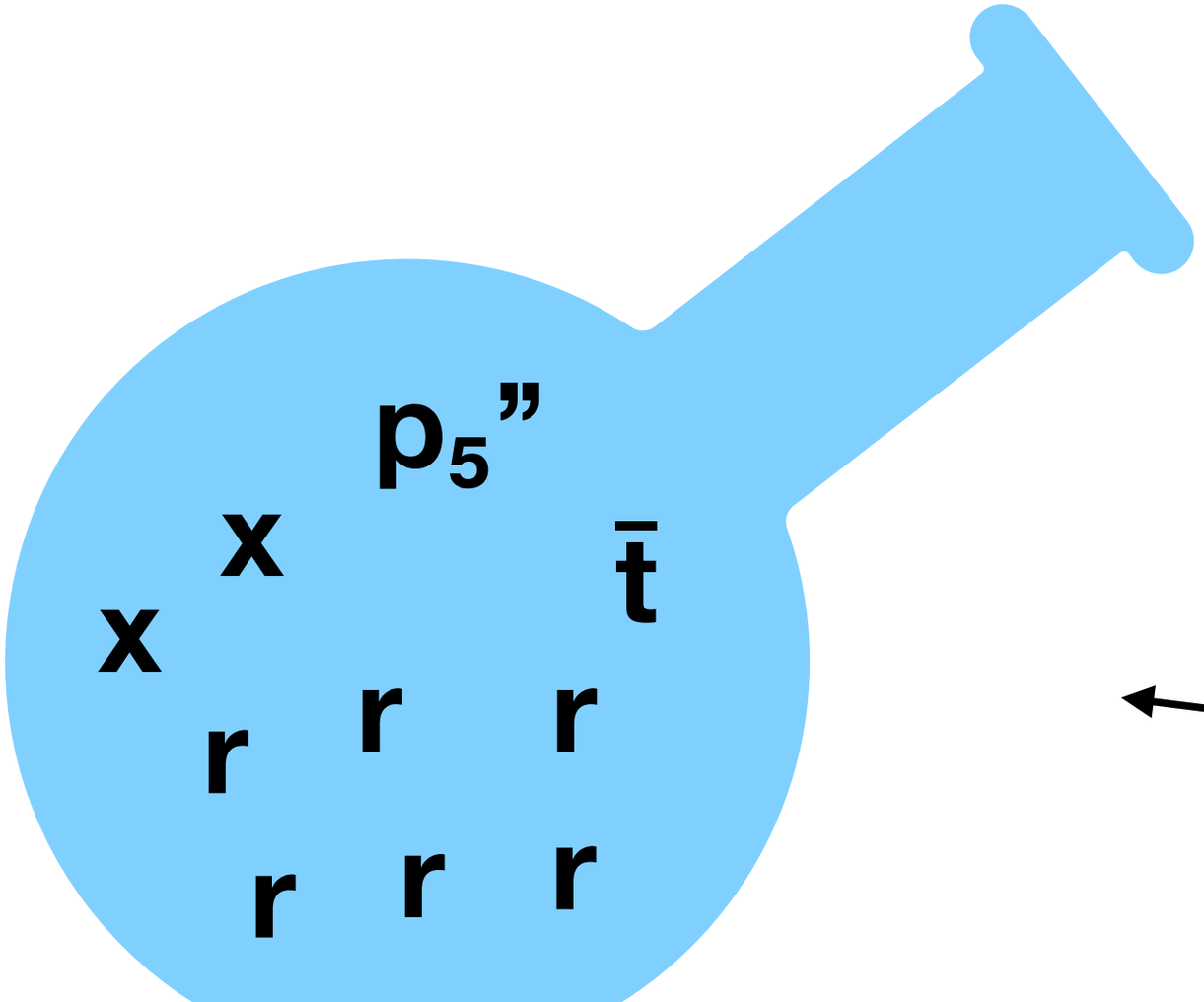
$p_5 \rightarrow p_5' + \bar{t}$

$\bar{t} + t \rightarrow t'$

$p_5' \rightarrow p_5''$

$p_5'' + t' \rightarrow p_6$

👉 $p_5'' + \bar{t} \rightarrow p_1$



s’il n’y a pas de t

Instructions → réactions

5: dec(t), 6, 1

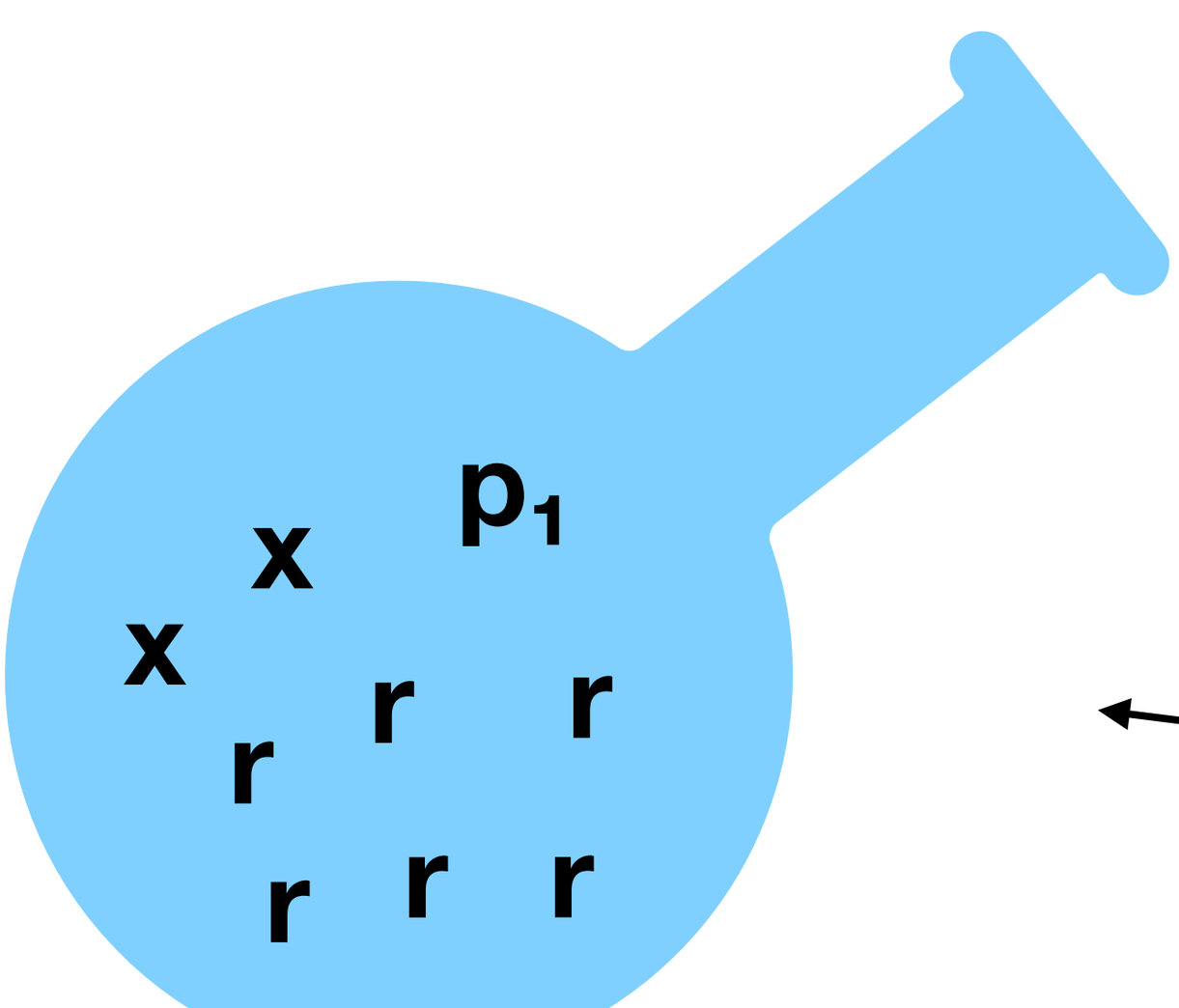
$p_5 \rightarrow p_5' + \bar{t}$

$\bar{t} + t \rightarrow t'$

$p_5' \rightarrow p_5''$

$p_5'' + t' \rightarrow p_6$

$p_5'' + \bar{t} \rightarrow p_1$



s'il n'y a pas de t

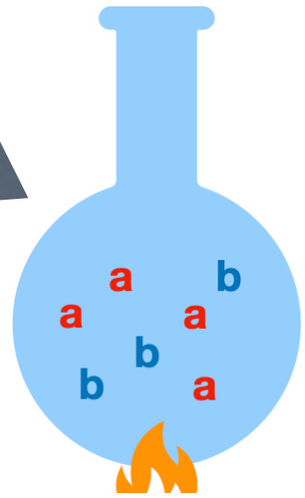
Exercice 6 du TD8

Conclusions

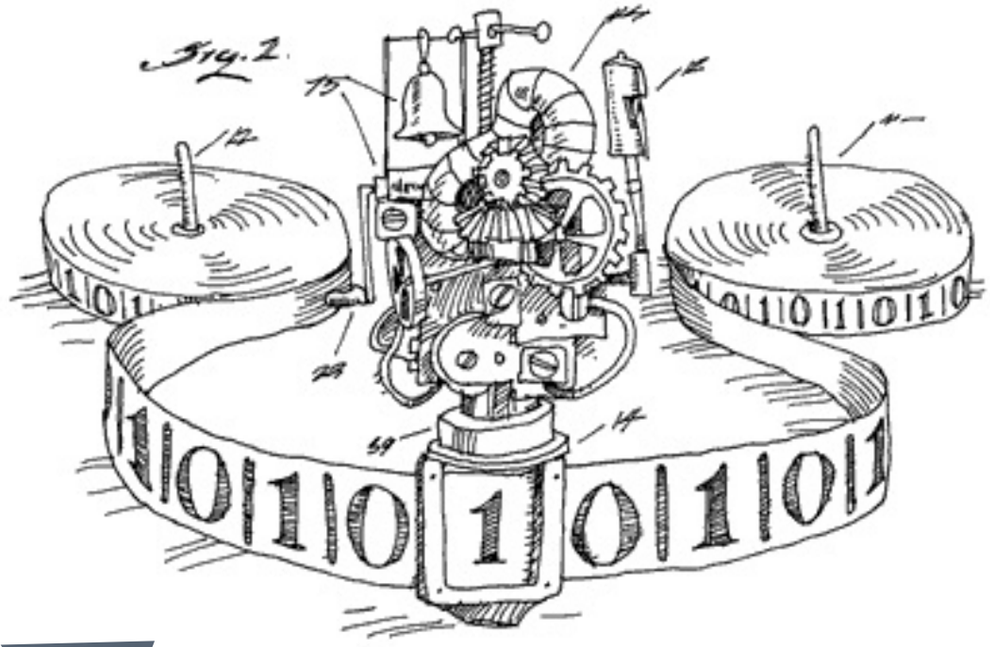
- On peut définir des modèles de calcul à partir de phénomènes naturels non conventionnels
- Soit du type physique, soit chimique, soit biologique
- Certains modèles, comme celui basé sur les réactions chimiques, peuvent simuler n’importe quel algorithme

0	2	1	2
x	y	t	r

1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
👉 6: inc(x), 5
7: stop



a → c
b → c



Machines de Turing

Pseudo-code / Python

itérations

```
Pour .. de .. à .. faire
   ..
FinPour

Tant que .. faire
   ..
FinTantQue
```

fonctions

```
fonction abc(arguments) :
   ..
   retourner(..)
```

conditionnelles

```
Si .. alors
   ..
FinSi

Si .. alors
   ..
Sinon
   ..
FinSi
```

écriture/lecture

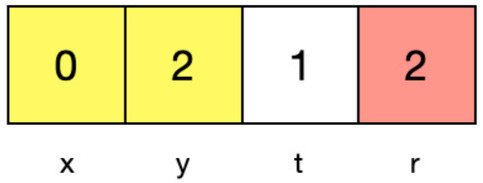
```
écrire(« .. »)
réponse := lire()
```

variables

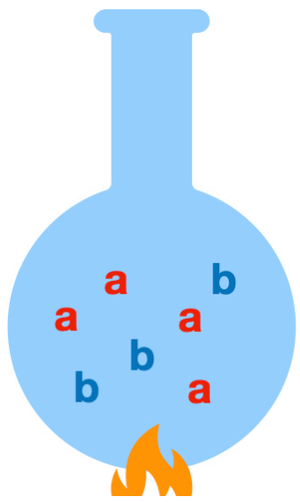
```
x := 3
y := 2
x := x+y
```

λ-calcul

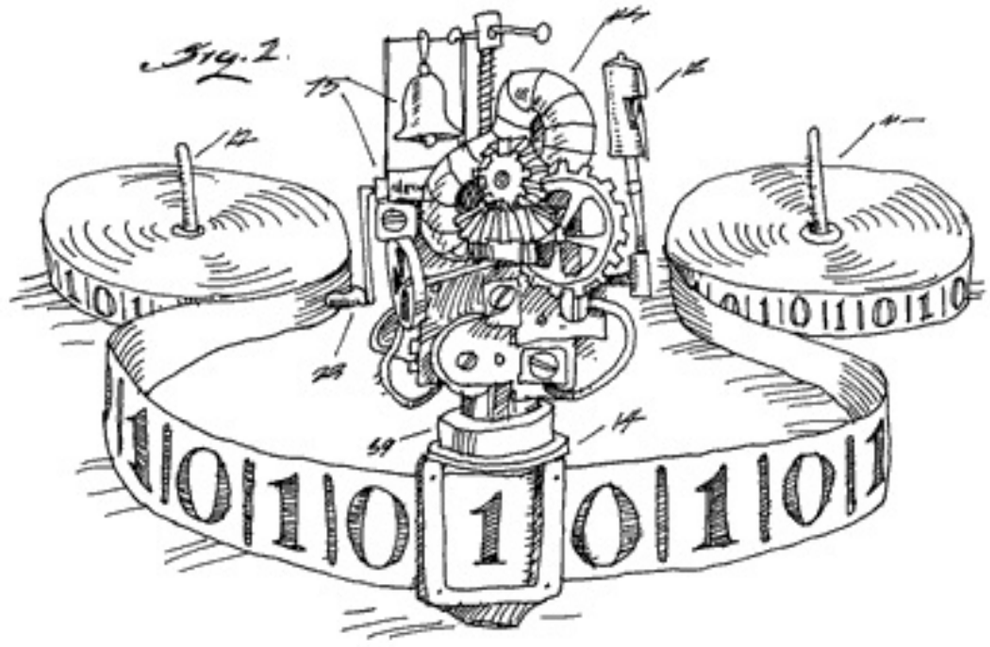
$$\lambda z\,(z\,(\lambda x\,\lambda y\,y))\,(\lambda x\,\lambda y\,x)$$



1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
👉 6: inc(x), 5
7: stop



a → c
b → c



Machines de Turing

Pseudo-code / Python

itérations

```
Pour .. de .. à .. faire
   ..
FinPour

Tant que .. faire
   ..
FinTantQue
```

fonctions

```
fonction abc(arguments) :
   ..
   retourner(..)
```

conditionnelles

```
Si .. alors
   ..
FinSi

Si .. alors
   ..
Sinon
   ..
FinSi
```

écriture/lecture

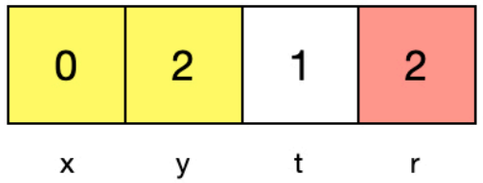
```
écrire(« .. »)
réponse := lire()
```

variables

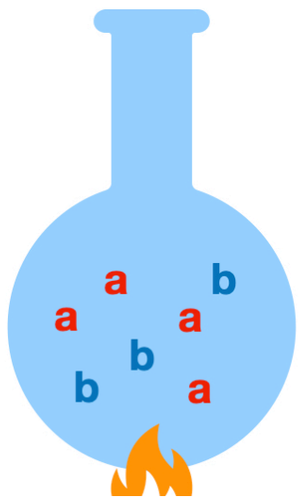
```
x := 3
y := 2
x := x+y
```

λ-calcul

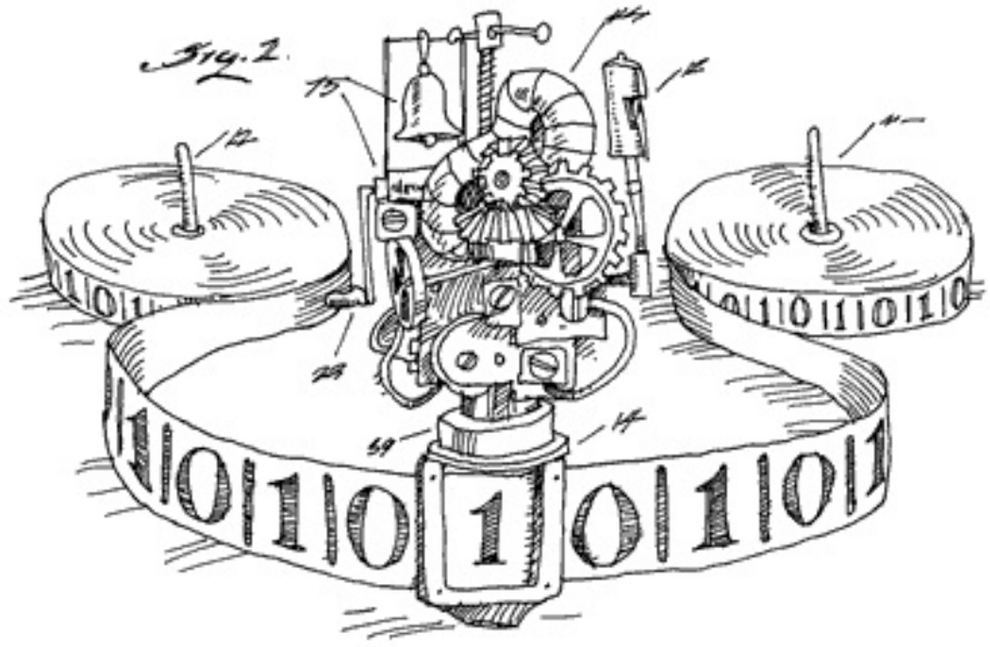
$$\lambda z \left(z \left(\lambda x \, \lambda y \, y \right) \right) \left(\lambda x \, \lambda y \, x \right)$$



1: dec(y), 2, 7
2: dec(x), 3, 5
3: inc(r), 4
4: inc(t), 2
5: dec(t), 6, 1
👉 6: inc(x), 5
7: stop



a → c
b → c



Machines de Turing

Tous ces modèles de « calcul »
sont équivalents.

Pseudo-code / Python

itérations

```
Pour .. de .. à .. faire
   ..
FinPour

Tant que .. faire
   ..
FinTantQue
```

fonctions

```
fonction abc(arguments) :
   ..
   retourner(..)
```

conditionnelles

```
Si .. alors
   ..
FinSi

Si .. alors
   ..
Sinon
   ..
FinSi
```

écriture/lecture

```
écrire(« .. »)
réponse := lire()
```

variables

```
x := 3
y := 2
x := x+y
```

λ-calcul

$$\lambda z \left(z \left(\lambda x \, \lambda y \, y \right) \right) \left(\lambda x \, \lambda y \, x \right)$$

The End