**SBML Model Report**

# Model name: "Hermansen2015 - denovo biosynthesis of pyrimidines in yeast"

May 5, 2016

## 1 General Overview

This is a document in SBML Level 2 Version 4 format. This model was created by the following two authors: Brian Mannakee[1] and Ryan Gutenkunst[2] at December tenth 2015 at 1:40 p. m. and last time modified at December tenth 2015 at 1:40 p. m. Table 1 gives an overview of the quantities of all components of this model.

Table 1: Number of components in this model, which are described in the following sections.

| Element | Quantity | Element | Quantity |
|---|---|---|---|
| compartment types | 0 | compartments | 1 |
| species types | 0 | species | 9 |
| events | 0 | constraints | 0 |
| reactions | 20 | function definitions | 20 |
| global parameters | 30 | unit definitions | 2 |
| rules | 0 | initial assignments | 0 |

### Model Notes

Hermansen2015 - denovo biosynthesis of pyrimidines in yeast

This model is described in the article:Characterizing selective pressures on the pathway for de novo biosynthesis of pyrimidines in yeast. Hermansen RA , Mannakee BK , Knecht W , Liberles DA , Gutenkunst RNBMC Evolutionary Biology. 2015, 15:232

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Abstract:

Selection on proteins is typically measured with the assumption that each protein acts independently. However, selection more likely acts at higher levels of biological organization, requiring an integrative view of protein function. Here, we built a kinetic model for de novo pyrimidine biosynthesis in the yeast Saccharomyces cerevisiae to relate pathway function to selective pressures on individual protein-encoding genes.Gene families across yeast were constructed for each member of the pathway and the ratio of nonsynonymous to synonymous nucleotide substitution rates (dN/dS) was estimated for each enzyme from S. cerevisiae and closely related species. We found a positive relationship between the influence that each enzyme has on pathway function and its selective constraint.We expect this trend to be locally present for enzymes that have pathway control, but over longer evolutionary timescales we expect that mutation-selection balance may change the enzymes that have pathway control.

This model is hosted on BioModels Database and identified by: MODEL1512160000.

To cite BioModels Database, please use: BioModels Database: An enhanced, curated and annotated resource for published quantitative kinetic models.



## 2 Unit Definitions

This is an overview of five unit definitions of which three are predefined by SBML and not mentioned in the model.

### 2.1 Unit `time`

**Name** time

**Definition** 3600 s

### 2.2 Unit `substance`

**Name** substance

**Definition** mmol

### 2.3 Unit `volume`

**Notes** Litre is the predefined SBML unit for `volume`.

**Definition** l

### 2.4 Unit `area`

**Notes** Square metre is the predefined SBML unit for `area` since SBML Level 2 Version 1.

**Definition** $m^2$

### 2.5 Unit `length`

**Notes** Metre is the predefined SBML unit for `length` since SBML Level 2 Version 1.

**Definition** m

## 3 Compartment

This model contains one compartment.

Table 2: Properties of all compartments.

| Id | Name | SBO | Spatial Dimensions | Size | Unit | Constant | Outside |
|---|---|---|---|---|---|---|---|
| `compartment` | compartment | | 3 | 1 | litre | ☑ | |

### 3.1 Compartment `compartment`

This is a three dimensional compartment with a constant size of one litre.

**Name** compartment

## 4 Species

This model contains nine species. Section 8 provides further details and the derived rates of change of each species.

Table 3: Properties of each species.

| Id | Name | Compartment | Derived Unit | Constant | Boundary Condition |
|---|---|---|---|---|---|
| cp | cp | compartment | $\mathrm{mmol} \cdot \mathrm{l}^{-1}$ | ⊟ | ⊟ |
| ca | ca | compartment | $\mathrm{mmol} \cdot \mathrm{l}^{-1}$ | ⊟ | ⊟ |
| dho | dho | compartment | $\mathrm{mmol} \cdot \mathrm{l}^{-1}$ | ⊟ | ⊟ |
| oro | oro | compartment | $\mathrm{mmol} \cdot \mathrm{l}^{-1}$ | ⊟ | ⊟ |
| omp | omp | compartment | $\mathrm{mmol} \cdot \mathrm{l}^{-1}$ | ⊟ | ⊟ |
| ump | ump | compartment | $\mathrm{mmol} \cdot \mathrm{l}^{-1}$ | ⊟ | ⊟ |
| udp | udp | compartment | $\mathrm{mmol} \cdot \mathrm{l}^{-1}$ | ⊟ | ⊟ |
| utp | utp | compartment | $\mathrm{mmol} \cdot \mathrm{l}^{-1}$ | ⊟ | ⊟ |
| ctp | ctp | compartment | $\mathrm{mmol} \cdot \mathrm{l}^{-1}$ | ⊟ | ⊟ |

## 5 Parameters

This model contains 30 global parameters.

Table 4: Properties of each parameter.

| Id | Name | SBO | Value | Unit | Constant |
|---|---|---|---|---|---|
| vmax1 | vmax1 | | 3.616 | | ☑ |
| bc | [bc] | | 1.523 | | ☑ |
| glu | [glu] | | 0.546 | | ☑ |
| K_utp | K_utp | | 1.414 | | ☑ |
| K_q | K_q | | 0.058 | | ☑ |
| K_bc | K_bc | | 2.372 | | ☑ |
| vmax2 | vmax2 | | 2.446 | | ☑ |
| asp | [asp] | | 0.097 | | ☑ |
| atp | [atp] | | 0.151 | | ☑ |
| K_atp | K_atp | | 1.289 | | ☑ |
| K_m2 | K_m2 | | 2.005 | | ☑ |
| vmax3 | vmax3 | | 28.661 | | ☑ |
| K_m3 | K_m3 | | 1.272 | | ☑ |
| vmax4 | vmax4 | | 91.780 | | ☑ |
| K_m4 | K_m4 | | 0.016 | | ☑ |
| vmax5 | vmax5 | | 5227.497 | | ☑ |
| K_m5 | K_m5 | | 0.020 | | ☑ |
| prpp | [prpp] | | 0.182 | | ☑ |
| vmax6 | vmax6 | | 34.972 | | ☑ |
| K_m6 | K_m6 | | 20.341 | | ☑ |
| vmax10 | vmax10 | | 6.555 | | ☑ |
| K_m10 | K_m10 | | 0.027 | | ☑ |
| vmax7 | vmax7 | | 5.831 | | ☑ |
| K_m7 | K_m7 | | 0.166 | | ☑ |
| g_pyr | g_pyr | | 0.198 | | ☑ |
| K_Mp | K_Mp | | 5.487 | | ☑ |
| vmax8 | vmax8 | | 0.163 | | ☑ |
| K_m8 | K_m8 | | 0.004 | | ☑ |
| K_asp | K_asp | | 0.168 | | ☑ |
| d | d | | 0.100 | | ☑ |

## 6 Function definitions

This is an overview of 20 function definitions.

## 6.1 Function definition Function_for_r2

**Name** Function for r2

**Arguments** K_asp, K_m2, K_utp, asp, vol (compartment), [cp], [utp], vmax2

**Mathematical Expression**

$$\frac{\frac{\text{vmax2}\cdot[\text{cp}]\cdot\text{asp}}{\left(1+\frac{[\text{utp}]}{\text{K\_utp}}\right)\cdot(\text{K\_m2}+[\text{cp}])\cdot(\text{K\_asp}+\text{asp})}}{\text{vol}\,(\text{compartment})} \tag{1}$$

## 6.2 Function definition Function_for_r1

**Name** Function for r1

**Arguments** K_atp, K_bc, K_q, K_utp, atp, bc, vol (compartment), glu, [utp], vmax1

**Mathematical Expression**

$$\frac{\frac{\text{vmax1}\cdot\text{bc}\cdot\text{glu}\cdot\text{atp}}{\left(1+\frac{[\text{utp}]}{\text{K\_utp}}\right)\cdot(\text{K\_atp}+\text{atp})\cdot(\text{K\_bc}+\text{bc})\cdot(\text{K\_q}+\text{glu})}}{\text{vol}\,(\text{compartment})} \tag{2}$$

## 6.3 Function definition Function_for_r3

**Name** Function for r3

**Arguments** K_m3, [ca], vol (compartment), vmax3

**Mathematical Expression**

$$\frac{\frac{\text{vmax3}\cdot[\text{ca}]}{\text{K\_m3}+[\text{ca}]}}{\text{vol}\,(\text{compartment})} \tag{3}$$

## 6.4 Function definition Function_for_r4

**Name** Function for r4

**Arguments** K_m4, vol (compartment), [dho], vmax4

**Mathematical Expression**

$$\frac{\frac{\text{vmax4}\cdot[\text{dho}]}{\text{K\_m4}+[\text{dho}]}}{\text{vol}\,(\text{compartment})} \tag{4}$$

## 6.5 Function definition Function_for_r5

**Name** Function for r5

**Arguments** K_m5, vol(compartment), [oro], prpp, vmax5

**Mathematical Expression**

$$\frac{\frac{\text{vmax5}\cdot[\text{oro}]\cdot\text{prpp}}{\text{K\_m5}+[\text{oro}]\cdot\text{prpp}}}{\text{vol}\,(\text{compartment})} \tag{5}$$

## 6.6 Function definition Function_for_r6

**Name** Function for r6

**Arguments** K_m6, vol(compartment), [omp], vmax6

**Mathematical Expression**

$$\frac{\frac{\text{vmax6}\cdot[\text{omp}]}{\text{K\_m6}+[\text{omp}]}}{\text{vol}\,(\text{compartment})} \tag{6}$$

## 6.7 Function definition Function_for_r10

**Name** Function for r10

**Arguments** K_m10, vol(compartment), [ump], vmax10

**Mathematical Expression**

$$\frac{\frac{\text{vmax10}\cdot[\text{ump}]}{\text{K\_m10}+[\text{ump}]}}{\text{vol}\,(\text{compartment})} \tag{7}$$

## 6.8 Function definition Function_for_r7

**Name** Function for r7

**Arguments** K_m7, vol(compartment), [udp], vmax7

**Mathematical Expression**

$$\frac{\frac{\text{vmax7}\cdot[\text{udp}]}{\text{K\_m7}+[\text{udp}]}}{\text{vol}\,(\text{compartment})} \tag{8}$$

### 6.9 Function definition Function_for_utp_degradation

**Name** Function for utp_degradation

**Arguments** K_Mp, vol (compartment), g_pyr, [utp]

**Mathematical Expression**

$$\frac{\frac{\text{g\_pyr}\cdot[\text{utp}]}{\text{K\_Mp}+[\text{utp}]}}{\text{vol}\,(\text{compartment})} \tag{9}$$

### 6.10 Function definition Function_for_r8

**Name** Function for r8

**Arguments** K_m8, vol (compartment), [utp], vmax8

**Mathematical Expression**

$$\frac{\frac{\text{vmax8}\cdot[\text{utp}]}{\text{K\_m8}+[\text{utp}]}}{\text{vol}\,(\text{compartment})} \tag{10}$$

### 6.11 Function definition Function_for_ctp_degradation

**Name** Function for ctp_degradation

**Arguments** K_Mp, vol (compartment), [ctp], g_pyr

**Mathematical Expression**

$$\frac{\frac{\text{g\_pyr}\cdot[\text{ctp}]}{\text{K\_Mp}+[\text{ctp}]}}{\text{vol}\,(\text{compartment})} \tag{11}$$

### 6.12 Function definition Function_for_cp_dilution

**Name** Function for cp_dilution

**Arguments** vol (compartment), [cp], d

**Mathematical Expression**

$$\frac{\text{d}\cdot[\text{cp}]}{\text{vol}\,(\text{compartment})} \tag{12}$$

### 6.13 Function definition Function_for_ca_dilution

**Name** Function for ca_dilution

**Arguments** [ca], vol (compartment), d

**Mathematical Expression**

$$\frac{\mathrm{d} \cdot [\mathrm{ca}]}{\mathrm{vol}\,(\mathrm{compartment})} \tag{13}$$

### 6.14 Function definition Function_for_dho_dilution

**Name** Function for dho_dilution

**Arguments** vol (compartment), d, [dho]

**Mathematical Expression**

$$\frac{\mathrm{d} \cdot [\mathrm{dho}]}{\mathrm{vol}\,(\mathrm{compartment})} \tag{14}$$

### 6.15 Function definition Function_for_oro_dilution

**Name** Function for oro_dilution

**Arguments** vol (compartment), d, [oro]

**Mathematical Expression**

$$\frac{\mathrm{d} \cdot [\mathrm{oro}]}{\mathrm{vol}\,(\mathrm{compartment})} \tag{15}$$

### 6.16 Function definition Function_for_omp_dilution

**Name** Function for omp_dilution

**Arguments** vol (compartment), d, [omp]

**Mathematical Expression**

$$\frac{\mathrm{d} \cdot [\mathrm{omp}]}{\mathrm{vol}\,(\mathrm{compartment})} \tag{16}$$

### 6.17 Function definition Function_for_ump_dilution

**Name** Function for ump_dilution

**Arguments** vol (compartment), d, [ump]

**Mathematical Expression**

$$\frac{\mathrm{d} \cdot [\mathrm{ump}]}{\mathrm{vol}\,(\mathrm{compartment})} \tag{17}$$

### 6.18 Function definition Function_for_udp_dilution

**Name** Function for udp_dilution

**Arguments** vol (compartment), d, [udp]

**Mathematical Expression**

$$\frac{\mathrm{d} \cdot [\mathrm{udp}]}{\mathrm{vol}\,(\mathrm{compartment})} \tag{18}$$

### 6.19 Function definition Function_for_utp_dilution

**Name** Function for utp_dilution

**Arguments** vol (compartment), d, [utp]

**Mathematical Expression**

$$\frac{\mathrm{d} \cdot [\mathrm{utp}]}{\mathrm{vol}\,(\mathrm{compartment})} \tag{19}$$

### 6.20 Function definition Function_for_ctp_dilution

**Name** Function for ctp_dilution

**Arguments** vol (compartment), [ctp], d

**Mathematical Expression**

$$\frac{\mathrm{d} \cdot [\mathrm{ctp}]}{\mathrm{vol}\,(\mathrm{compartment})} \tag{20}$$

## 7 Reactions

This model contains 20 reactions. All reactions are listed in the following table and are subsequently described in detail. If a reaction is affected by a modifier, the identifier of this species is written above the reaction arrow.

Table 5: Overview of all reactions

| № | Id | Name | Reaction Equation | SBO |
|---|---|---|---|---|
| 1 | r1 | r1 | $\emptyset \overset{\text{utp, utp}}{\rightleftharpoons} \text{cp}$ | |
| 2 | r2 | r2 | $\text{cp} \overset{\text{utp, cp, utp}}{\rightleftharpoons} \text{ca}$ | |
| 3 | r3 | r3 | $\text{ca} \overset{\text{ca}}{\rightleftharpoons} \text{dho}$ | |
| 4 | r4 | r4 | $\text{dho} \overset{\text{dho}}{\rightleftharpoons} \text{oro}$ | |
| 5 | r5 | r5 | $\text{oro} \overset{\text{oro}}{\rightleftharpoons} \text{omp}$ | |
| 6 | r6 | r6 | $\text{omp} \overset{\text{omp}}{\rightleftharpoons} \text{ump}$ | |
| 7 | r10 | r10 | $\text{ump} \overset{\text{ump}}{\rightleftharpoons} \text{udp}$ | |
| 8 | r7 | r7 | $\text{udp} \overset{\text{udp}}{\rightleftharpoons} \text{utp}$ | |
| 9 | utp_degradation | utp_degradation | $\text{utp} \overset{\text{utp}}{\rightleftharpoons} \emptyset$ | |
| 10 | r8 | r8 | $\text{utp} \overset{\text{utp}}{\rightleftharpoons} \text{ctp}$ | |
| 11 | ctp_degradation | ctp_degradation | $\text{ctp} \overset{\text{ctp}}{\rightleftharpoons} \emptyset$ | |
| 12 | cp_dilution | cp_dilution | $\text{cp} \overset{\text{cp}}{\rightleftharpoons} \emptyset$ | |
| 13 | ca_dilution | ca_dilution | $\text{ca} \overset{\text{ca}}{\rightleftharpoons} \emptyset$ | |
| 14 | dho_dilution | dho_dilution | $\text{dho} \overset{\text{dho}}{\rightleftharpoons} \emptyset$ | |
| 15 | oro_dilution | oro_dilution | $\text{oro} \overset{\text{oro}}{\rightleftharpoons} \emptyset$ | |
| 16 | omp_dilution | omp_dilution | $\text{omp} \overset{\text{omp}}{\rightleftharpoons} \emptyset$ | |

| № | Id | Name | Reaction Equation | SBO |
|---|---|---|---|---|
| 17 | ump_dilution | ump_dilution | $\text{ump} \overset{\text{ump}}{\rightleftharpoons} \emptyset$ | |
| 18 | udp_dilution | udp_dilution | $\text{udp} \overset{\text{udp}}{\rightleftharpoons} \emptyset$ | |
| 19 | utp_dilution | utp_dilution | $\text{utp} \overset{\text{utp}}{\rightleftharpoons} \emptyset$ | |
| 20 | ctp_dilution | ctp_dilution | $\text{ctp} \overset{\text{ctp}}{\rightleftharpoons} \emptyset$ | |

## 7.1 Reaction r1

This is a reversible reaction of no reactant forming one product influenced by two modifiers.

**Name** r1

### Reaction equation

$$\emptyset \xrightleftharpoons{\text{utp, utp}} \text{cp} \tag{21}$$

### Modifiers

Table 6: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| utp | utp | |
| utp | utp | |

### Product

Table 7: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| cp | cp | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_1 = \text{vol}\left(\text{compartment}\right) \cdot \text{Function\_for\_r1}\left(\text{K\_atp}, \text{K\_bc}, \text{K\_q}, \text{K\_utp}, \text{atp}, \text{bc}, \text{vol}\left(\text{compartment}\right), \text{glu}, [\text{utp}], \text{vmax1}\right) \tag{22}$$

$$\text{Function\_for\_r1}\left(\text{K\_atp}, \text{K\_bc}, \text{K\_q}, \text{K\_utp}, \text{atp}, \text{bc}, \text{vol}\left(\text{compartment}\right), \text{glu}, [\text{utp}], \text{vmax1}\right) = \frac{\frac{\text{vmax1} \cdot \text{bc} \cdot \text{glu} \cdot \text{atp}}{\left(1 + \frac{[\text{utp}]}{\text{K\_utp}}\right) \cdot (\text{K\_atp} + \text{atp}) \cdot (\text{K\_bc} + \text{bc}) \cdot (\text{K\_q} + \text{glu})}}{\text{vol}\left(\text{compartment}\right)} \tag{23}$$

$$\text{Function\_for\_r1}\left(\text{K\_atp}, \text{K\_bc}, \text{K\_q}, \text{K\_utp}, \text{atp}, \text{bc}, \text{vol}\left(\text{compartment}\right), \text{glu}, [\text{utp}], \text{vmax1}\right) = \frac{\frac{\text{vmax1} \cdot \text{bc} \cdot \text{glu} \cdot \text{atp}}{\left(1 + \frac{[\text{utp}]}{\text{K\_utp}}\right) \cdot (\text{K\_atp} + \text{atp}) \cdot (\text{K\_bc} + \text{bc}) \cdot (\text{K\_q} + \text{glu})}}{\text{vol}\left(\text{compartment}\right)} \tag{24}$$

## 7.2 Reaction r2

This is a reversible reaction of one reactant forming one product influenced by three modifiers.

**Name** r2

### Reaction equation

$$\mathrm{cp} \overset{\mathrm{utp,\ cp,\ utp}}{\rightleftharpoons} \mathrm{ca} \tag{25}$$

### Reactant

Table 8: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| cp | cp | |

### Modifiers

Table 9: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| utp | utp | |
| cp | cp | |
| utp | utp | |

### Product

Table 10: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| ca | ca | |

### Kinetic Law

**Derived unit** contains undeclared units

$$\begin{aligned} v_2 = {} & \mathrm{vol}\left(\mathrm{compartment}\right) \\ & \cdot \mathrm{Function\_for\_r2}\left(\mathrm{K\_asp}, \mathrm{K\_m2}, \mathrm{K\_utp}, \mathrm{asp}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{cp}], [\mathrm{utp}], \mathrm{vmax2}\right) \end{aligned} \tag{26}$$

$$\text{Function\_for\_r2}\left(\text{K\_asp}, \text{K\_m2}, \text{K\_utp}, \text{asp}, \text{vol}\left(\text{compartment}\right), [\text{cp}], [\text{utp}], \text{vmax2}\right) = \frac{\frac{\text{vmax2} \cdot [\text{cp}] \cdot \text{asp}}{\left(1 + \frac{[\text{utp}]}{\text{K\_utp}}\right) \cdot (\text{K\_m2} + [\text{cp}]) \cdot (\text{K\_asp} + \text{asp})}}{\text{vol}\left(\text{compartment}\right)} \tag{27}$$

$$\text{Function\_for\_r2}\left(\text{K\_asp}, \text{K\_m2}, \text{K\_utp}, \text{asp}, \text{vol}\left(\text{compartment}\right), [\text{cp}], [\text{utp}], \text{vmax2}\right) = \frac{\frac{\text{vmax2} \cdot [\text{cp}] \cdot \text{asp}}{\left(1 + \frac{[\text{utp}]}{\text{K\_utp}}\right) \cdot (\text{K\_m2} + [\text{cp}]) \cdot (\text{K\_asp} + \text{asp})}}{\text{vol}\left(\text{compartment}\right)} \tag{28}$$

## 7.3 Reaction r3

This is a reversible reaction of one reactant forming one product influenced by one modifier.

**Name** r3

### Reaction equation

$$\text{ca} \overset{\text{ca}}{\rightleftharpoons} \text{dho} \tag{29}$$

### Reactant

Table 11: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| ca | ca | |

### Modifier

Table 12: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| ca | ca | |

### Product

Table 13: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| dho | dho | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_3 = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_r3}\left(\mathrm{K\_m3}, [\mathrm{ca}], \mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{vmax3}\right) \quad (30)$$

$$\mathrm{Function\_for\_r3}\left(\mathrm{K\_m3}, [\mathrm{ca}], \mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{vmax3}\right) = \frac{\frac{\mathrm{vmax3} \cdot [\mathrm{ca}]}{\mathrm{K\_m3} + [\mathrm{ca}]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (31)$$

$$\mathrm{Function\_for\_r3}\left(\mathrm{K\_m3}, [\mathrm{ca}], \mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{vmax3}\right) = \frac{\frac{\mathrm{vmax3} \cdot [\mathrm{ca}]}{\mathrm{K\_m3} + [\mathrm{ca}]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (32)$$

## 7.4 Reaction `r4`

This is a reversible reaction of one reactant forming one product influenced by one modifier.

**Name** r4

### Reaction equation

$$\mathrm{dho} \overset{\mathrm{dho}}{\rightleftharpoons} \mathrm{oro} \quad (33)$$

### Reactant

Table 14: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| `dho` | dho | |

### Modifier

Table 15: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| `dho` | dho | |

### Product

Table 16: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| oro | oro | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_4 = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_r4}\left(\mathrm{K\_m4}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{dho}], \mathrm{vmax4}\right) \quad (34)$$

$$\mathrm{Function\_for\_r4}\left(\mathrm{K\_m4}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{dho}], \mathrm{vmax4}\right) = \frac{\frac{\mathrm{vmax4} \cdot [\mathrm{dho}]}{\mathrm{K\_m4} + [\mathrm{dho}]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (35)$$

$$\mathrm{Function\_for\_r4}\left(\mathrm{K\_m4}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{dho}], \mathrm{vmax4}\right) = \frac{\frac{\mathrm{vmax4} \cdot [\mathrm{dho}]}{\mathrm{K\_m4} + [\mathrm{dho}]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (36)$$

## 7.5 Reaction r5

This is a reversible reaction of one reactant forming one product influenced by one modifier.

**Name** r5

### Reaction equation

$$\mathrm{oro} \underset{\longleftarrow}{\overset{\mathrm{oro}}{\rightleftharpoons}} \mathrm{omp} \quad (37)$$

### Reactant

Table 17: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| oro | oro | |

### Modifier

Table 18: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| oro | oro | |

### Product

Table 19: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| omp | omp | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_5 = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_r5}\left(\mathrm{K\_m5}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{oro}], \mathrm{prpp}, \mathrm{vmax5}\right) \quad (38)$$

$$\mathrm{Function\_for\_r5}\left(\mathrm{K\_m5}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{oro}], \mathrm{prpp}, \mathrm{vmax5}\right) = \frac{\frac{\mathrm{vmax5} \cdot [\mathrm{oro}] \cdot \mathrm{prpp}}{\mathrm{K\_m5} + [\mathrm{oro}] \cdot \mathrm{prpp}}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (39)$$

$$\mathrm{Function\_for\_r5}\left(\mathrm{K\_m5}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{oro}], \mathrm{prpp}, \mathrm{vmax5}\right) = \frac{\frac{\mathrm{vmax5} \cdot [\mathrm{oro}] \cdot \mathrm{prpp}}{\mathrm{K\_m5} + [\mathrm{oro}] \cdot \mathrm{prpp}}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (40)$$

## 7.6 Reaction r6

This is a reversible reaction of one reactant forming one product influenced by one modifier.

**Name** r6

### Reaction equation

$$\mathrm{omp} \underset{\leftarrow}{\overset{\mathrm{omp}}{\rightleftharpoons}} \mathrm{ump} \quad (41)$$

### Reactant

Table 20: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| omp | omp | |

### Modifier

Table 21: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| omp | omp | |

### Product

Table 22: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| ump | ump | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_6 = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_r6}\left(\mathrm{K\_m6}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{omp}], \mathrm{vmax6}\right) \quad (42)$$

$$\mathrm{Function\_for\_r6}\left(\mathrm{K\_m6}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{omp}], \mathrm{vmax6}\right) = \frac{\frac{\mathrm{vmax6} \cdot [\mathrm{omp}]}{\mathrm{K\_m6} + [\mathrm{omp}]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (43)$$

$$\mathrm{Function\_for\_r6}\left(\mathrm{K\_m6}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{omp}], \mathrm{vmax6}\right) = \frac{\frac{\mathrm{vmax6} \cdot [\mathrm{omp}]}{\mathrm{K\_m6} + [\mathrm{omp}]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (44)$$

## 7.7 Reaction r10

This is a reversible reaction of one reactant forming one product influenced by one modifier.

**Name** r10

### Reaction equation

$$\mathrm{ump} \underset{\mathrm{ump}}{\rightleftharpoons} \mathrm{udp} \quad (45)$$

### Reactant

Table 23: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| ump | ump | |

### Modifier

Table 24: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| ump | ump | |

### Product

Table 25: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| udp | udp | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_7 = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_r10}\left(\mathrm{K\_m10}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{ump}], \mathrm{vmax10}\right) \quad (46)$$

$$\mathrm{Function\_for\_r10}\left(\mathrm{K\_m10}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{ump}], \mathrm{vmax10}\right) = \frac{\frac{\mathrm{vmax10} \cdot [\mathrm{ump}]}{\mathrm{K\_m10} + [\mathrm{ump}]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (47)$$

$$\mathrm{Function\_for\_r10}\left(\mathrm{K\_m10}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{ump}], \mathrm{vmax10}\right) = \frac{\frac{\mathrm{vmax10} \cdot [\mathrm{ump}]}{\mathrm{K\_m10} + [\mathrm{ump}]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (48)$$

## 7.8 Reaction r7

This is a reversible reaction of one reactant forming one product influenced by one modifier.

**Name** r7

### Reaction equation

$$\mathrm{udp} \underset{\longleftarrow}{\overset{\mathrm{udp}}{\rightleftharpoons}} \mathrm{utp} \quad (49)$$

### Reactant

Table 26: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| udp | udp | |

### Modifier

Table 27: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| udp | udp | |

### Product

Table 28: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| utp | utp | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_8 = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_r7}\left(\mathrm{K\_m7}, \mathrm{vol}\left(\mathrm{compartment}\right), \left[\mathrm{udp}\right], \mathrm{vmax7}\right) \quad (50)$$

$$\mathrm{Function\_for\_r7}\left(\mathrm{K\_m7}, \mathrm{vol}\left(\mathrm{compartment}\right), \left[\mathrm{udp}\right], \mathrm{vmax7}\right) = \frac{\frac{\mathrm{vmax7} \cdot \left[\mathrm{udp}\right]}{\mathrm{K\_m7} + \left[\mathrm{udp}\right]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (51)$$

$$\mathrm{Function\_for\_r7}\left(\mathrm{K\_m7}, \mathrm{vol}\left(\mathrm{compartment}\right), \left[\mathrm{udp}\right], \mathrm{vmax7}\right) = \frac{\frac{\mathrm{vmax7} \cdot \left[\mathrm{udp}\right]}{\mathrm{K\_m7} + \left[\mathrm{udp}\right]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (52)$$

## 7.9 Reaction utp_degradation

This is a reversible reaction of one reactant forming no product influenced by one modifier.

**Name** utp_degradation

### Reaction equation

$$\mathrm{utp} \underset{\searrow}{\overset{\mathrm{utp}}{\rightleftharpoons}} \emptyset \quad (53)$$

### Reactant

Table 29: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| utp | utp | |

### Modifier

Table 30: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| utp | utp | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_9 = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_utp\_degradation}\left(\mathrm{K\_Mp}, \mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{g\_pyr}, [\mathrm{utp}]\right) \tag{54}$$

$$\mathrm{Function\_for\_utp\_degradation}\left(\mathrm{K\_Mp}, \mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{g\_pyr}, [\mathrm{utp}]\right) = \frac{\frac{\mathrm{g\_pyr} \cdot [\mathrm{utp}]}{\mathrm{K\_Mp} + [\mathrm{utp}]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \tag{55}$$

$$\mathrm{Function\_for\_utp\_degradation}\left(\mathrm{K\_Mp}, \mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{g\_pyr}, [\mathrm{utp}]\right) = \frac{\frac{\mathrm{g\_pyr} \cdot [\mathrm{utp}]}{\mathrm{K\_Mp} + [\mathrm{utp}]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \tag{56}$$

## 7.10 Reaction r8

This is a reversible reaction of one reactant forming one product influenced by one modifier.

**Name** r8

### Reaction equation

$$\mathrm{utp} \underset{\longleftarrow}{\overset{\mathrm{utp}}{\rightleftharpoons}} \mathrm{ctp} \tag{57}$$

### Reactant

Table 31: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| utp | utp | |

### Modifier

Table 32: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| utp | utp | |

### Product

Table 33: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| ctp | ctp | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{10} = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_r8}\left(\mathrm{K\_m8}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{utp}], \mathrm{vmax8}\right) \quad (58)$$

$$\mathrm{Function\_for\_r8}\left(\mathrm{K\_m8}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{utp}], \mathrm{vmax8}\right) = \frac{\frac{\mathrm{vmax8} \cdot [\mathrm{utp}]}{\mathrm{K\_m8} + [\mathrm{utp}]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (59)$$

$$\mathrm{Function\_for\_r8}\left(\mathrm{K\_m8}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{utp}], \mathrm{vmax8}\right) = \frac{\frac{\mathrm{vmax8} \cdot [\mathrm{utp}]}{\mathrm{K\_m8} + [\mathrm{utp}]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (60)$$

## 7.11 Reaction ctp_degradation

This is a reversible reaction of one reactant forming no product influenced by one modifier.

**Name** ctp_degradation

### Reaction equation

$$\mathrm{ctp} \overset{\mathrm{ctp}}{\rightleftharpoons} \emptyset \quad (61)$$

### Reactant

Table 34: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| ctp | ctp | |

### Modifier

Table 35: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| ctp | ctp | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{11} = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_ctp\_degradation}\left(\mathrm{K\_Mp}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{ctp}], \mathrm{g\_pyr}\right) \tag{62}$$

$$\mathrm{Function\_for\_ctp\_degradation}\left(\mathrm{K\_Mp}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{ctp}], \mathrm{g\_pyr}\right) = \frac{\frac{\mathrm{g\_pyr} \cdot [\mathrm{ctp}]}{\mathrm{K\_Mp} + [\mathrm{ctp}]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \tag{63}$$

$$\mathrm{Function\_for\_ctp\_degradation}\left(\mathrm{K\_Mp}, \mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{ctp}], \mathrm{g\_pyr}\right) = \frac{\frac{\mathrm{g\_pyr} \cdot [\mathrm{ctp}]}{\mathrm{K\_Mp} + [\mathrm{ctp}]}}{\mathrm{vol}\left(\mathrm{compartment}\right)} \tag{64}$$

## 7.12 Reaction cp_dilution

This is a reversible reaction of one reactant forming no product influenced by one modifier.

**Name** cp_dilution

### Reaction equation

$$\mathrm{cp} \overset{\mathrm{cp}}{\rightleftharpoons} \emptyset \tag{65}$$

### Reactant

Table 36: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| cp | cp | |

### Modifier

Table 37: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| cp | cp | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{12} = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_cp\_dilution}\left(\mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{cp}], \mathrm{d}\right) \tag{66}$$

$$\mathrm{Function\_for\_cp\_dilution}\left(\mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{cp}], \mathrm{d}\right) = \frac{\mathrm{d} \cdot [\mathrm{cp}]}{\mathrm{vol}\left(\mathrm{compartment}\right)} \tag{67}$$

$$\mathrm{Function\_for\_cp\_dilution}\left(\mathrm{vol}\left(\mathrm{compartment}\right), [\mathrm{cp}], \mathrm{d}\right) = \frac{\mathrm{d} \cdot [\mathrm{cp}]}{\mathrm{vol}\left(\mathrm{compartment}\right)} \tag{68}$$

## 7.13 Reaction ca_dilution

This is a reversible reaction of one reactant forming no product influenced by one modifier.

**Name** ca_dilution

### Reaction equation

$$\mathrm{ca} \overset{\mathrm{ca}}{\rightleftharpoons} \emptyset \tag{69}$$

### Reactant

Table 38: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| ca | ca | |

### Modifier

Table 39: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| ca | ca | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{13} = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_ca\_dilution}\left(\left[\mathrm{ca}\right], \mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{d}\right) \tag{70}$$

$$\mathrm{Function\_for\_ca\_dilution}\left(\left[\mathrm{ca}\right], \mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{d}\right) = \frac{\mathrm{d} \cdot \left[\mathrm{ca}\right]}{\mathrm{vol}\left(\mathrm{compartment}\right)} \tag{71}$$

$$\mathrm{Function\_for\_ca\_dilution}\left(\left[\mathrm{ca}\right], \mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{d}\right) = \frac{\mathrm{d} \cdot \left[\mathrm{ca}\right]}{\mathrm{vol}\left(\mathrm{compartment}\right)} \tag{72}$$

## 7.14 Reaction dho_dilution

This is a reversible reaction of one reactant forming no product influenced by one modifier.

**Name** dho_dilution

### Reaction equation

$$\mathrm{dho} \xrightleftharpoons{\mathrm{dho}} \emptyset \tag{73}$$

### Reactant

Table 40: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| dho | dho | |

### Modifier

Table 41: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| dho | dho | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{14} = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_dho\_dilution}\left(\mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{d}, [\mathrm{dho}]\right) \quad (74)$$

$$\mathrm{Function\_for\_dho\_dilution}\left(\mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{d}, [\mathrm{dho}]\right) = \frac{\mathrm{d} \cdot [\mathrm{dho}]}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (75)$$

$$\mathrm{Function\_for\_dho\_dilution}\left(\mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{d}, [\mathrm{dho}]\right) = \frac{\mathrm{d} \cdot [\mathrm{dho}]}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (76)$$

## 7.15 Reaction oro_dilution

This is a reversible reaction of one reactant forming no product influenced by one modifier.

**Name** oro_dilution

### Reaction equation

$$\mathrm{oro} \overset{\mathrm{oro}}{\rightleftharpoons} \emptyset \quad (77)$$

### Reactant

Table 42: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| oro | oro | |

### Modifier

Table 43: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| oro | oro | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{15} = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_oro\_dilution}\left(\mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{d}, [\mathrm{oro}]\right) \quad (78)$$

$$\mathrm{Function\_for\_oro\_dilution}\left(\mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{d}, [\mathrm{oro}]\right) = \frac{\mathrm{d} \cdot [\mathrm{oro}]}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (79)$$

$$\mathrm{Function\_for\_oro\_dilution}\left(\mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{d}, [\mathrm{oro}]\right) = \frac{\mathrm{d} \cdot [\mathrm{oro}]}{\mathrm{vol}\left(\mathrm{compartment}\right)} \quad (80)$$

## 7.16 Reaction `omp_dilution`

This is a reversible reaction of one reactant forming no product influenced by one modifier.

**Name** omp_dilution

### Reaction equation

$$\mathrm{omp} \overset{\mathrm{omp}}{\rightleftharpoons} \emptyset \quad (81)$$

### Reactant

Table 44: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| `omp` | omp | |

### Modifier

Table 45: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| `omp` | omp | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{16} = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_omp\_dilution}\left(\mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{d}, [\mathrm{omp}]\right) \quad (82)$$

$$\text{Function\_for\_omp\_dilution}\left(\text{vol}\left(\text{compartment}\right), \text{d}, [\text{omp}]\right) = \frac{\text{d} \cdot [\text{omp}]}{\text{vol}\left(\text{compartment}\right)} \tag{83}$$

$$\text{Function\_for\_omp\_dilution}\left(\text{vol}\left(\text{compartment}\right), \text{d}, [\text{omp}]\right) = \frac{\text{d} \cdot [\text{omp}]}{\text{vol}\left(\text{compartment}\right)} \tag{84}$$

## 7.17 Reaction `ump_dilution`

This is a reversible reaction of one reactant forming no product influenced by one modifier.

**Name** ump_dilution

### Reaction equation

$$\text{ump} \overset{\text{ump}}{\rightleftharpoons} \emptyset \tag{85}$$

### Reactant

Table 46: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| `ump` | ump | |

### Modifier

Table 47: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| `ump` | ump | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{17} = \text{vol}\left(\text{compartment}\right) \cdot \text{Function\_for\_ump\_dilution}\left(\text{vol}\left(\text{compartment}\right), \text{d}, [\text{ump}]\right) \tag{86}$$

$$\text{Function\_for\_ump\_dilution}\left(\text{vol}\left(\text{compartment}\right), \text{d}, [\text{ump}]\right) = \frac{\text{d} \cdot [\text{ump}]}{\text{vol}\left(\text{compartment}\right)} \tag{87}$$

$$\text{Function\_for\_ump\_dilution}\left(\text{vol}\left(\text{compartment}\right), \text{d}, [\text{ump}]\right) = \frac{\text{d} \cdot [\text{ump}]}{\text{vol}\left(\text{compartment}\right)} \tag{88}$$

## 7.18 Reaction udp_dilution

This is a reversible reaction of one reactant forming no product influenced by one modifier.

**Name** udp_dilution

### Reaction equation

$$\mathrm{udp} \overset{\mathrm{udp}}{\rightleftharpoons} \emptyset \tag{89}$$

### Reactant

Table 48: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| udp | udp | |

### Modifier

Table 49: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| udp | udp | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{18} = \mathrm{vol}\left(\mathrm{compartment}\right) \cdot \mathrm{Function\_for\_udp\_dilution}\left(\mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{d}, [\mathrm{udp}]\right) \tag{90}$$

$$\mathrm{Function\_for\_udp\_dilution}\left(\mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{d}, [\mathrm{udp}]\right) = \frac{\mathrm{d} \cdot [\mathrm{udp}]}{\mathrm{vol}\left(\mathrm{compartment}\right)} \tag{91}$$

$$\mathrm{Function\_for\_udp\_dilution}\left(\mathrm{vol}\left(\mathrm{compartment}\right), \mathrm{d}, [\mathrm{udp}]\right) = \frac{\mathrm{d} \cdot [\mathrm{udp}]}{\mathrm{vol}\left(\mathrm{compartment}\right)} \tag{92}$$

## 7.19 Reaction utp_dilution

This is a reversible reaction of one reactant forming no product influenced by one modifier.

**Name** utp_dilution

### Reaction equation

$$\text{utp} \underset{}{\overset{\text{utp}}{\rightleftharpoons}} \emptyset \tag{93}$$

### Reactant

Table 50: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| utp | utp | |

### Modifier

Table 51: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| utp | utp | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{19} = \text{vol}\left(\text{compartment}\right) \cdot \text{Function\_for\_utp\_dilution}\left(\text{vol}\left(\text{compartment}\right), \text{d}, [\text{utp}]\right) \tag{94}$$

$$\text{Function\_for\_utp\_dilution}\left(\text{vol}\left(\text{compartment}\right), \text{d}, [\text{utp}]\right) = \frac{\text{d} \cdot [\text{utp}]}{\text{vol}\left(\text{compartment}\right)} \tag{95}$$

$$\text{Function\_for\_utp\_dilution}\left(\text{vol}\left(\text{compartment}\right), \text{d}, [\text{utp}]\right) = \frac{\text{d} \cdot [\text{utp}]}{\text{vol}\left(\text{compartment}\right)} \tag{96}$$

## 7.20 Reaction `ctp_dilution`

This is a reversible reaction of one reactant forming no product influenced by one modifier.

**Name** ctp_dilution

### Reaction equation

$$\text{ctp} \underset{}{\overset{\text{ctp}}{\rightleftharpoons}} \emptyset \tag{97}$$

### Reactant

Table 52: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| ctp | ctp | |

### Modifier

Table 53: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| ctp | ctp | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{20} = \text{vol}\left(\text{compartment}\right) \cdot \text{Function\_for\_ctp\_dilution}\left(\text{vol}\left(\text{compartment}\right), [\text{ctp}], \text{d}\right) \quad (98)$$

$$\text{Function\_for\_ctp\_dilution}\left(\text{vol}\left(\text{compartment}\right), [\text{ctp}], \text{d}\right) = \frac{\text{d} \cdot [\text{ctp}]}{\text{vol}\left(\text{compartment}\right)} \quad (99)$$

$$\text{Function\_for\_ctp\_dilution}\left(\text{vol}\left(\text{compartment}\right), [\text{ctp}], \text{d}\right) = \frac{\text{d} \cdot [\text{ctp}]}{\text{vol}\left(\text{compartment}\right)} \quad (100)$$

## 8 Derived Rate Equations

When interpreted as an ordinary differential equation framework, this model implies the following set of equations for the rates of change of each species.

Identifiers for kinetic laws highlighted in gray cannot be verified to evaluate to units of SBML `substance` per `time`. As a result, some SBML interpreters may not be able to verify the consistency of the units on quantities in the model. Please check if

- parameters without an unit definition are involved or
- volume correction is necessary because the `hasOnlySubstanceUnits` flag may be set to `false` and `spacialDimensions`$> 0$ for certain species.

### 8.1 Species cp

**Name** cp

**Initial concentration** $3.7 \cdot 10^{-4}$ mmol $\cdot$ l$^{-1}$

This species takes part in five reactions (as a reactant in r2, cp_dilution and as a product in r1 and as a modifier in r2, cp_dilution).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{cp} = v_1 - v_2 - v_{12} \tag{101}$$

## 8.2 Species ca

**Name** ca

**Initial concentration** $3.7 \cdot 10^{-4}\ \mathrm{mmol} \cdot \mathrm{l}^{-1}$

This species takes part in five reactions (as a reactant in r3, ca_dilution and as a product in r2 and as a modifier in r3, ca_dilution).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ca} = v_2 - v_3 - v_{13} \tag{102}$$

## 8.3 Species dho

**Name** dho

**Initial concentration** $3.7 \cdot 10^{-4}\ \mathrm{mmol} \cdot \mathrm{l}^{-1}$

This species takes part in five reactions (as a reactant in r4, dho_dilution and as a product in r3 and as a modifier in r4, dho_dilution).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{dho} = v_3 - v_4 - v_{14} \tag{103}$$

## 8.4 Species oro

**Name** oro

**Initial concentration** $3.7 \cdot 10^{-4}\ \mathrm{mmol} \cdot \mathrm{l}^{-1}$

This species takes part in five reactions (as a reactant in r5, oro_dilution and as a product in r4 and as a modifier in r5, oro_dilution).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{oro} = v_4 - v_5 - v_{15} \tag{104}$$

## 8.5 Species omp

**Name** omp

**Initial concentration** $3.7 \cdot 10^{-4}\ \mathrm{mmol} \cdot \mathrm{l}^{-1}$

This species takes part in five reactions (as a reactant in r6, omp_dilution and as a product in r5 and as a modifier in r6, omp_dilution).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{omp} = v_5 - v_6 - v_{16} \tag{105}$$

## 8.6 Species ump

**Name** ump

**Initial concentration** $3.7 \cdot 10^{-4}$ mmol $\cdot$ l$^{-1}$

This species takes part in five reactions (as a reactant in r10, ump_dilution and as a product in r6 and as a modifier in r10, ump_dilution).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ump} = v_6 - v_7 - v_{17} \tag{106}$$

## 8.7 Species udp

**Name** udp

**Initial concentration** 0.002886 mmol $\cdot$ l$^{-1}$

This species takes part in five reactions (as a reactant in r7, udp_dilution and as a product in r10 and as a modifier in r7, udp_dilution).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{udp} = v_7 - v_8 - v_{18} \tag{107}$$

## 8.8 Species utp

**Name** utp

**Initial concentration** 0.00666 mmol $\cdot$ l$^{-1}$

This species takes part in eleven reactions (as a reactant in utp_degradation, r8, utp_dilution and as a product in r7 and as a modifier in r1, r1, r2, r2, utp_degradation, r8, utp_dilution).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{utp} = v_8 - v_9 - v_{10} - v_{19} \tag{108}$$

## 8.9 Species ctp

**Name** ctp

**Initial concentration** $3.7 \cdot 10^{-4}$ mmol $\cdot$ l$^{-1}$

This species takes part in five reactions (as a reactant in ctp_degradation, ctp_dilution and as a product in r8 and as a modifier in ctp_degradation, ctp_dilution).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ctp} = v_{10} - v_{11} - v_{20} \tag{109}$$

SBML2LaTeX was developed by Andreas Dräger[a], Hannes Planatscher[a], Dieudonné M Wouamba[a], Adrian Schröder[a], Michael Hucka[b], Lukas Endler[c], Martin Golebiewski[d] and Andreas Zell[a]. Please see http://www.ra.cs.uni-tuebingen.de/software/SBML2LaTeX for more information.

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