SBML Model Report

Model name: "Arnold2011_Giersch1990_CalvinCycle"

May 6, 2016

1 General Overview

This is a document in SBML Level 2 Version 4 format. This model was created by the following three authors: Vijayalakshmi Chelliah[1], Anne Arnold[2] and Zoran Nikoloski[3] at October 19th 2011 at 2:53 p. m. and last time modified at April eighth 2016 at 5:10 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	2
species types	0	species	11
events	0	constraints	0
reactions	6	function definitions	6
global parameters	2	unit definitions	2
rules	1	initial assignments	0

Model Notes

This model is from the article:
A quantitative comparison of CalvinBenson cycle models

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Anne Arnold, Zoran Nikoloski Trends in Plant Science2011 Oct 14. 22001849,

Abstract:
The Calvin-Benson cycle (CBC) provides the precursors for biomass synthesis necessary for plant growth. The dynamic behavior and yield of the CBC depend on the environmental conditions and regulation of the cellular state. Accurate quantitative models hold the promise of identifying the key determinants of the tightly regulated CBC function and their effects on the responses in future climates. We provide an integrative analysis of the largest compendium of existing models for photosynthetic processes. Based on the proposed ranking, our framework facilitates the discovery of best-performing models with regard to metabolomics data and of candidates for metabolic engineering.

Note: Model of the Calvin cycle by Giersch et al. (1990, DOI:10.1007/BF00032595). The parameter values are taken from Figure 4 and 5. The initial metabolite values are chosen from the data set of Zhu et al. (2007, DOI:10.1104/pp.107.103713). A detailed description of all modifications is given in the model described by Arnold and Nikoloski (2011, PMID:22001849.

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 `volume`

Definition l

2.2 Unit `substance`

Definition mmol

2.3 Unit `area`

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

Definition m^2

2.4 Unit `length`

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

Definition m

2.5 Unit `time`

Notes Second is the predefined SBML unit for `time`.

Definition s

3 Compartments

This model contains two compartments.

Table 2: Properties of all compartments.

Id	Name	SBO	Spatial Dimensions	Size	Unit	Constant	Outside
`chloroplast`	chloroplast		3	1	litre	☑	
`cytosol`	cytosol		3	1	litre	☑	

3.1 Compartment `chloroplast`

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

Name chloroplast

3.2 Compartment `cytosol`

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

Name cytosol

4 Species

This model contains eleven species. The boundary condition of four of these species is set to `true` so that these species' amount cannot be changed by any reaction. Section 9 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
RuBP	RuBP	chloroplast	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☐	☐
PGA	PGA	chloroplast	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☐	☐
TP	TP	chloroplast	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☐	☐
Ru5P	Ru5P	chloroplast	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☐	☐
Pi	Pi	chloroplast	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☐	☐
ATP	ATP	chloroplast	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☐	☐
ADP	ADP	chloroplast	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☐	☐
E_RuBisCO	RuBisCo	chloroplast	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑	☑
totRuBP	totRuBP	chloroplast	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☐	☑
TPc	TPc	cytosol	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑	☑
Pic	Pic	cytosol	$\mathrm{mmol} \cdot \mathrm{l}^{-1}$	☑	☑

5 Parameters

This model contains two global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
V6	V6	0000009	5.880		☑
P_0	P_0	0000009	16.000		☑

6 Function definitions

This is an overview of six function definitions.

6.1 Function definition function_6

Name PGA reduction

Arguments Vm, S1, S2, P1, P2, P3, k, K1, K2

Mathematical Expression

$$\frac{\mathrm{Vm} \cdot \left(\mathrm{S1} \cdot \mathrm{S2} - \frac{\mathrm{P1} \cdot \mathrm{P2} \cdot \mathrm{P3}}{\mathrm{k}}\right)}{\mathrm{K1} + \frac{\mathrm{S1} \cdot \mathrm{S2} \cdot \mathrm{K1}}{\mathrm{K2}} + \frac{\mathrm{P1} \cdot \mathrm{P2} \cdot \mathrm{P3}}{\mathrm{k}}} \tag{1}$$

6.2 Function definition function_5

Name High Substrate MM - RuBisCO

Arguments k, E, S, K

Mathematical Expression

$$\frac{\mathrm{k}}{2} \cdot \left(\mathrm{E} + \mathrm{S} + \mathrm{K} - \sqrt{2}\right) \tag{2}$$

6.3 Function definition function_7

Name MM s1 - reg (TP reduction)

Arguments Vm, S, K

Mathematical Expression

$$\frac{\mathrm{Vm} \cdot \mathrm{S}}{\mathrm{S} + \mathrm{K}} \tag{3}$$

6.4 Function definition function_8

Name RuBP regeneration

Arguments Vm, S1, S2, K1, K2, K3, R

Mathematical Expression

$$\frac{\mathrm{Vm} \cdot \mathrm{S1} \cdot \mathrm{S2}}{\mathrm{K1} \cdot \mathrm{K2} + \mathrm{K2} \cdot \mathrm{S2} + \mathrm{S1} \cdot \mathrm{S2} + \mathrm{K3} \cdot \mathrm{R}} \tag{4}$$

6.5 Function definition function_10

Name MM s2 - reg (ATP synthesis)

Arguments Vm, s1, s2, K1, K2

Mathematical Expression

$$\frac{\mathrm{Vm} \cdot \mathrm{s1} \cdot \mathrm{s2}}{(\mathrm{s1} + \mathrm{K1}) \cdot (\mathrm{s2} + \mathrm{K2})} \tag{5}$$

6.6 Function definition function_9

Name TP translocator

Arguments S1, S2, P1, P2, K2, K1, Vm

Mathematical Expression

$$\frac{\mathrm{Vm} \cdot (\mathrm{S1} \cdot \mathrm{S2} - \mathrm{P1} \cdot \mathrm{P2})}{(\mathrm{S1} + \mathrm{P1}) \cdot \mathrm{K2} + (\mathrm{S2} + \mathrm{P2}) \cdot \mathrm{K1} + \mathrm{K1} \cdot \mathrm{K2} \cdot \left(\frac{\mathrm{S1}}{\mathrm{K1}} + \frac{\mathrm{P2}}{\mathrm{K2}}\right) \cdot \left(\frac{\mathrm{S2}}{\mathrm{K2}} + \frac{\mathrm{P1}}{\mathrm{K1}}\right)} \tag{6}$$

7 Rule

This is an overview of one rule.

7.1 Rule totRuBP

Rule totRuBP is an assignment rule for species totRuBP:

$$\mathrm{totRuBP} = \frac{1}{2} \cdot (\mathrm{P\_0} - (\mathrm{[PGA]} + \mathrm{[TP]} + \mathrm{[Ru5P]} + \mathrm{[Pi]} + \mathrm{[ATP]})) \tag{7}$$

8 Reactions

This model contains six 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	RuBisCO	RuBisCO	$\mathrm{totRuBP} + \mathrm{RuBP} \xrightarrow{\mathrm{E\_RuBisCO}} 2\,\mathrm{PGA}$	
2	PGA_red	PGA reduction	$\mathrm{PGA} + \mathrm{ATP} \rightleftharpoons \mathrm{ADP} + \mathrm{TP} + \mathrm{Pi}$	
3	TP_red	TP reduction	$5\,\mathrm{TP} \longrightarrow 3\,\mathrm{Ru5P} + 2\,\mathrm{Pi}$	
4	RuBP_reg	RuBP regeneration	$\mathrm{Ru5P} + \mathrm{ATP} \xrightarrow{\mathrm{Pi}} \mathrm{RuBP} + \mathrm{ADP}$	
5	TPT	TP translocator	$\mathrm{TP} + \mathrm{Pic} \rightleftharpoons \mathrm{TPc} + \mathrm{Pi}$	
6	ATP_S	ATP synthesis	$\mathrm{ADP} + \mathrm{Pi} \longrightarrow \mathrm{ATP}$	

8.1 Reaction RuBisCO

This is an irreversible reaction of two reactants forming one product influenced by one modifier.

Name RuBisCO

Reaction equation

$$\text{totRuBP} + \text{RuBP} \xrightarrow{\text{E\_RuBisCO}} 2\,\text{PGA} \tag{8}$$

Reactants

Table 6: Properties of each reactant.

Id	Name	SBO
totRuBP	totRuBP	
RuBP	RuBP	

Modifier

Table 7: Properties of each modifier.

Id	Name	SBO
E_RuBisCO	RuBisCo	

Product

Table 8: Properties of each product.

Id	Name	SBO
PGA	PGA	

Kinetic Law

Derived unit contains undeclared units

$$v_1 = \text{vol}\left(\text{chloroplast}\right) \cdot \text{function\_5}\left(\text{k}, [\text{E\_RuBisCO}], [\text{totRuBP}], \text{K}\right) \tag{9}$$

$$\text{function\_5}\left(\text{k}, \text{E}, \text{S}, \text{K}\right) = \frac{\text{k}}{2} \cdot \left(\text{E} + \text{S} + \text{K} - \sqrt{2}\right) \tag{10}$$

$$\text{function\_5}\left(\text{k}, \text{E}, \text{S}, \text{K}\right) = \frac{\text{k}}{2} \cdot \left(\text{E} + \text{S} + \text{K} - \sqrt{2}\right) \tag{11}$$

Table 9: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k	k	0000009	0.504		☑
K	K	0000009	0.040		☑

8.2 Reaction PGA_red

This is a reversible reaction of two reactants forming three products.

Name PGA reduction

Reaction equation

$$\mathrm{PGA} + \mathrm{ATP} \rightleftharpoons \mathrm{ADP} + \mathrm{TP} + \mathrm{Pi} \tag{12}$$

Reactants

Table 10: Properties of each reactant.

Id	Name	SBO
PGA	PGA	
ATP	ATP	

Products

Table 11: Properties of each product.

Id	Name	SBO
ADP	ADP	
TP	TP	
Pi	Pi	

Kinetic Law

Derived unit contains undeclared units

$$v_2 = \mathrm{vol}\left(\mathrm{chloroplast}\right) \cdot \mathrm{function\_6}\left(\mathrm{Vm}, [\mathrm{PGA}], [\mathrm{ATP}], [\mathrm{ADP}], [\mathrm{TP}], [\mathrm{Pi}], \mathrm{k}, \mathrm{K1}, \mathrm{K2}\right) \tag{13}$$

$$\mathrm{function\_6}\left(\mathrm{Vm}, \mathrm{S1}, \mathrm{S2}, \mathrm{P1}, \mathrm{P2}, \mathrm{P3}, \mathrm{k}, \mathrm{K1}, \mathrm{K2}\right) = \frac{\mathrm{Vm} \cdot \left(\mathrm{S1} \cdot \mathrm{S2} - \frac{\mathrm{P1} \cdot \mathrm{P2} \cdot \mathrm{P3}}{\mathrm{k}}\right)}{\mathrm{K1} + \frac{\mathrm{S1} \cdot \mathrm{S2} \cdot \mathrm{K1}}{\mathrm{K2}} + \frac{\mathrm{P1} \cdot \mathrm{P2} \cdot \mathrm{P3}}{\mathrm{k}}} \tag{14}$$

$$\text{function\_6}(\text{Vm},\text{S1},\text{S2},\text{P1},\text{P2},\text{P3},\text{k},\text{K1},\text{K2}) = \frac{\text{Vm}\cdot\left(\text{S1}\cdot\text{S2}-\frac{\text{P1}\cdot\text{P2}\cdot\text{P3}}{\text{k}}\right)}{\text{K1}+\frac{\text{S1}\cdot\text{S2}\cdot\text{K1}}{\text{K2}}+\frac{\text{P1}\cdot\text{P2}\cdot\text{P3}}{\text{k}}} \tag{15}$$

Table 12: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vm	Vm	0000009	3.49		☑
k	k	0000009	14.00		☑
K1	K1	0000009	1.00		☑
K2	K2	0000009	1.00		☑

8.3 Reaction TP_red

This is an irreversible reaction of one reactant forming two products.

Name TP reduction

Reaction equation

$$5\,\text{TP} \longrightarrow 3\,\text{Ru5P} + 2\,\text{Pi} \tag{16}$$

Reactant

Table 13: Properties of each reactant.

Id	Name	SBO
TP	TP	

Products

Table 14: Properties of each product.

Id	Name	SBO
Ru5P	Ru5P	
Pi	Pi	

Kinetic Law

Derived unit contains undeclared units

$$v_3 = \text{vol}(\text{chloroplast})\cdot\text{function\_7}(\text{Vm},[\text{TP}],\text{K}) \tag{17}$$

$$\text{function\_7}(\text{Vm}, \text{S}, \text{K}) = \frac{\text{Vm} \cdot \text{S}}{\text{S} + \text{K}} \tag{18}$$

$$\text{function\_7}(\text{Vm}, \text{S}, \text{K}) = \frac{\text{Vm} \cdot \text{S}}{\text{S} + \text{K}} \tag{19}$$

Table 15: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vm	Vm	0000009	1.06		☑
K	K	0000009	0.40		☑

8.4 Reaction RuBP_reg

This is an irreversible reaction of two reactants forming two products influenced by one modifier.

Name RuBP regeneration

Reaction equation

$$\text{Ru5P} + \text{ATP} \xrightarrow{\text{Pi}} \text{RuBP} + \text{ADP} \tag{20}$$

Reactants

Table 16: Properties of each reactant.

Id	Name	SBO
Ru5P	Ru5P	
ATP	ATP	

Modifier

Table 17: Properties of each modifier.

Id	Name	SBO
Pi	Pi	

Products

Table 18: Properties of each product.

Id	Name	SBO
RuBP	RuBP	
ADP	ADP	

Kinetic Law

Derived unit contains undeclared units

$$v_4 = \mathrm{vol}\,(\mathrm{chloroplast}) \cdot \mathrm{function\_8}\,(\mathrm{Vm}, [\mathrm{Ru5P}], [\mathrm{ATP}], \mathrm{K1}, \mathrm{K2}, \mathrm{K3}, [\mathrm{Pi}]) \tag{21}$$

$$\mathrm{function\_8}\,(\mathrm{Vm}, \mathrm{S1}, \mathrm{S2}, \mathrm{K1}, \mathrm{K2}, \mathrm{K3}, \mathrm{R}) = \frac{\mathrm{Vm} \cdot \mathrm{S1} \cdot \mathrm{S2}}{\mathrm{K1} \cdot \mathrm{K2} + \mathrm{K2} \cdot \mathrm{S2} + \mathrm{S1} \cdot \mathrm{S2} + \mathrm{K3} \cdot \mathrm{R}} \tag{22}$$

$$\mathrm{function\_8}\,(\mathrm{Vm}, \mathrm{S1}, \mathrm{S2}, \mathrm{K1}, \mathrm{K2}, \mathrm{K3}, \mathrm{R}) = \frac{\mathrm{Vm} \cdot \mathrm{S1} \cdot \mathrm{S2}}{\mathrm{K1} \cdot \mathrm{K2} + \mathrm{K2} \cdot \mathrm{S2} + \mathrm{S1} \cdot \mathrm{S2} + \mathrm{K3} \cdot \mathrm{R}} \tag{23}$$

Table 19: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
Vm	Vm	0000009	4.81		☑
K1	K1	0000009	0.05		☑
K2	K2	0000009	0.50		☑
K3	K3	0000009	0.05		☑

8.5 Reaction TPT

This is a reversible reaction of two reactants forming two products.

Name TP translocator

Reaction equation

$$\mathrm{TP} + \mathrm{Pic} \rightleftharpoons \mathrm{TPc} + \mathrm{Pi} \tag{24}$$

Reactants

Table 20: Properties of each reactant.

Id	Name	SBO
TP	TP	
Pic	Pic	

Products

Table 21: Properties of each product.

Id	Name	SBO
TPc	TPc	
Pi	Pi	

Kinetic Law

Derived unit contains undeclared units

$$v_5 = \text{function\_9}([\text{TP}], [\text{Pic}], [\text{TPc}], [\text{Pi}], \text{K2}, \text{K1}, \text{Vm}) \tag{25}$$

$$\begin{aligned} &\text{function\_9}(\text{S1}, \text{S2}, \text{P1}, \text{P2}, \text{K2}, \text{K1}, \text{Vm}) \\ &= \frac{\text{Vm} \cdot (\text{S1} \cdot \text{S2} - \text{P1} \cdot \text{P2})}{(\text{S1} + \text{P1}) \cdot \text{K2} + (\text{S2} + \text{P2}) \cdot \text{K1} + \text{K1} \cdot \text{K2} \cdot \left(\frac{\text{S1}}{\text{K1}} + \frac{\text{P2}}{\text{K2}}\right) \cdot \left(\frac{\text{S2}}{\text{K2}} + \frac{\text{P1}}{\text{K1}}\right)} \end{aligned} \tag{26}$$

Table 22: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
K2	K2	0000009	0.25		☑
K1	K1	0000009	0.08		☑
Vm	Vm	0000009	3.30		☑

8.6 Reaction ATP_S

This is an irreversible reaction of two reactants forming one product.

Name ATP synthesis

Reaction equation

$$\text{ADP} + \text{Pi} \longrightarrow \text{ATP} \tag{27}$$

Reactants

Table 23: Properties of each reactant.

Id	Name	SBO
ADP	ADP	
Pi	Pi	

Product

Table 24: Properties of each product.

Id	Name	SBO
ATP	ATP	

Kinetic Law

Derived unit contains undeclared units

$$v_6 = \text{vol}(\text{chloroplast}) \cdot \text{function\_10}(\text{V6}, [\text{ADP}], [\text{Pi}], \text{K1}, \text{K2}) \tag{28}$$

$$\text{function\_10}(\text{Vm}, \text{s1}, \text{s2}, \text{K1}, \text{K2}) = \frac{\text{Vm} \cdot \text{s1} \cdot \text{s2}}{(\text{s1} + \text{K1}) \cdot (\text{s2} + \text{K2})} \tag{29}$$

$$\text{function\_10}(\text{Vm}, \text{s1}, \text{s2}, \text{K1}, \text{K2}) = \frac{\text{Vm} \cdot \text{s1} \cdot \text{s2}}{(\text{s1} + \text{K1}) \cdot (\text{s2} + \text{K2})} \tag{30}$$

Table 25: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
K1	K1	0000009	0.08		☑
K2	K2	0000009	0.50		☑

9 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.

9.1 Species RuBP

Name RuBP

Initial concentration $2\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in RuBisCO and as a product in RuBP_reg).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{RuBP} = v_4 - v_1 \tag{31}$$

9.2 Species PGA

Name PGA

Initial concentration $2.4\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in PGA_red and as a product in RuBisCO).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{PGA} = 2\,v_1 - v_2 \tag{32}$$

9.3 Species TP

Name TP

Initial concentration $0.5\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in three reactions (as a reactant in TP_red, TPT and as a product in PGA_red).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{TP} = v_2 - 5\,v_3 - v_5 \tag{33}$$

9.4 Species Ru5P

Name Ru5P

Initial concentration $0.0500747384155456\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in RuBP_reg and as a product in TP_red).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ru5P} = 3\,v_3 - v_4 \tag{34}$$

9.5 Species Pi

Name Pi

Initial concentration $5\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in five reactions (as a reactant in ATP_S and as a product in PGA_red, TP_red, TPT and as a modifier in RuBP_reg).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Pi} = v_2 + 2\,v_3 + v_5 - v_6 \tag{35}$$

9.6 Species ATP

Name ATP

Initial concentration $0.68\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in three reactions (as a reactant in PGA_red, RuBP_reg and as a product in ATP_S).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ATP} = v_6 - v_2 - v_4 \tag{36}$$

9.7 Species ADP

Name ADP

Initial concentration $0.82\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in three reactions (as a reactant in ATP_S and as a product in PGA_red, RuBP_reg).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ADP} = v_2 + v_4 - v_6 \tag{37}$$

9.8 Species E_RuBisCO

Name RuBisCo

Initial concentration $3.56\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in one reaction (as a modifier in RuBisCO), which does not influence its rate of change because this constant species is on the boundary of the reaction system:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{E\_RuBisCO} = 0 \tag{38}$$

9.9 Species totRuBP

Name totRuBP

Initial concentration $3.68496263079223\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

Involved in rule totRuBP

This species takes part in one reaction (as a reactant in RuBisCO). Not this but one rule determines the species' quantity because this species is on the boundary of the reaction system.

9.10 Species TPc

Name TPc

Initial concentration $0.2\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in one reaction (as a product in TPT), which does not influence its rate of change because this constant species is on the boundary of the reaction system:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{TPc} = 0 \tag{39}$$

9.11 Species Pic

Name Pic

Initial concentration $1.4\ \mathrm{mmol}\cdot\mathrm{l}^{-1}$

This species takes part in one reaction (as a reactant in TPT), which does not influence its rate of change because this constant species is on the boundary of the reaction system:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Pic} = 0 \tag{40}$$

A Glossary of Systems Biology Ontology Terms

SBO:0000009 kinetic constant: Numerical parameter that quantifies the velocity of a chemical reaction

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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