SBML Model Report

Model name: "Arnold2011_Hahn1986-_CalvinCycle_Starch_Sucrose"

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 20th 2012 at 7:51 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	4
species types	0	species	22
events	0	constraints	0
reactions	18	function definitions	1
global parameters	4	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 Science 2011 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 and the related end-product pathways to starch and sucrose synthesis by Hahn (1986, [click here for abstract]). The parameter values are taken from Hahn (1984, [click here for abstract]). 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 ml

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 four 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	☑	
vacuole	vacuole		3	1	litre	☑	
phloem	phloem		3	1	litre	☑	

3.1 Compartment chloroplast

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

Name chloroplast

3.2 Compartment cytosol

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

Name cytosol

3.3 Compartment vacuole

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

Name vacuole

3.4 Compartment phloem

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

Name phloem

4 Species

This model contains 22 species. The boundary condition of three 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	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
PGA	PGA	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
TP	TP	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
HeP	HeP	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
TPGA	TPGA	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
E4P	E4P	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
S7P	S7P	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
Ru5P	Ru5P	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
GG	GG	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
ATP	ATP	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
ADP	ADP	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
UTP	UTP	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
UDP	UDP	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
Pi	Pi	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
CO2	CO2	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☑	☑
TPc	TPc	cytosol	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
HePc	HePc	cytosol	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
Suc	Suc	cytosol	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
Pic	Pic	cytosol	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
SucV	SucV	vacuole	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☐	☐
E	E	phloem	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☑	☑

Id	Name	Compartment	Derived Unit	Constant	Boundary Condition
Resp	Resp	chloroplast	$\mathrm{mmol} \cdot \mathrm{ml}^{-1}$	☑	☑

5 Parameters

This model contains four global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
r	r	0000009	$3 \cdot 10^{-5}$		☑
D	D	0000009	10^{-4}		☑
phi	phi	0000009	10^{-4}		☑
v_15	v(15)	0000009	0.010		☐

6 Function definition

This is an overview of one function definition.

6.1 Function definition function_1

Name irreversilbe Constant flux (Suc synth)

Argument v

Mathematical Expression

$$\mathrm{v} \tag{1}$$

7 Rule

This is an overview of one rule.

7.1 Rule v_15

Rule v_15 is an assignment rule for parameter v_15:

$$\mathrm{v\_15} = 0.0258 \cdot [\mathrm{HePc}] \cdot [\mathrm{UTP}] \tag{2}$$

8 Reactions

This model contains 18 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	$\mathrm{RuBP} + \mathrm{CO2} \longrightarrow 2\,\mathrm{PGA}$	
2	PGA_red	PGA reduction	$\mathrm{PGA} + \mathrm{ATP} \longrightarrow \mathrm{TP} + \mathrm{ADP} + \mathrm{Pi}$	
3	FBP_A_ase	FBP ald + ase	$2\,\mathrm{TP} \rightleftharpoons \mathrm{HeP} + \mathrm{Pi}$	
4	F6P_TK1	F6P trans I	$\mathrm{HeP} \longrightarrow \mathrm{TPGA} + \mathrm{E4P}$	
5	SBP_A_ase	SBP ald + ase	$\mathrm{E4P} + \mathrm{TP} \longrightarrow \mathrm{S7P} + \mathrm{Pi}$	
6	S7P_TK1_R5P_I	S7P trans I + R5P iso	$\mathrm{S7P} \longrightarrow \mathrm{TPGA} + \mathrm{Ru5P}$	
7	TK2_Ru5P_E	trans II + Ru5P epi	$\mathrm{TPGA} + \mathrm{TP} \longrightarrow \mathrm{Ru5P}$	
8	Ru5P_K	Ru5P kinase	$\mathrm{Ru5P} + \mathrm{ATP} \longrightarrow \mathrm{RuBP} + \mathrm{ADP}$	
9	ATP_S	ATP synthase	$\mathrm{ADP} + \mathrm{Pi} \longrightarrow \mathrm{ATP}$	
10	Starch_S	starch synthetase	$\mathrm{ATP} + \mathrm{HeP} \longrightarrow \mathrm{GG} + \mathrm{ADP} + 2\,\mathrm{Pi}$	
11	Starch_P	starch phosphorylase	$\mathrm{GG} + \mathrm{Pi} \longrightarrow \mathrm{HeP}$	
12	TPT	TP translocator	$\mathrm{TP} + \mathrm{Pic} \longrightarrow \mathrm{TPc} + \mathrm{Pi}$	
13	FBPc_A_ase	FBPc ald + ase	$2\,\mathrm{TPc} \longrightarrow \mathrm{HePc} + \mathrm{Pic}$	
14	Suc_S	sucrose synthetase	$2\,\mathrm{HePc} + \mathrm{UTP} \longrightarrow \mathrm{Suc} + \mathrm{UDP} + 3\,\mathrm{Pic}$	
15	UTP_S	UTP synthase	$\mathrm{UDP} + \mathrm{Pic} \longrightarrow \mathrm{UTP}$	
16	Respi	respiration rate	$\mathrm{Suc} \longrightarrow \mathrm{Resp}$	
17	Diffu	diffusion rate	$\mathrm{Suc} \rightleftharpoons \mathrm{SucV}$	
18	Transl	translocation rate	$\mathrm{Suc} \rightleftharpoons \mathrm{E}$	

8.1 Reaction RuBisCO

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

Name RuBisCO

Reaction equation

$$\mathrm{RuBP} + \mathrm{CO2} \longrightarrow 2\,\mathrm{PGA} \tag{3}$$

Reactants

Table 6: Properties of each reactant.

Id	Name	SBO
RuBP	RuBP	
CO2	CO2	

Product

Table 7: Properties of each product.

Id	Name	SBO
PGA	PGA	

Kinetic Law

Derived unit contains undeclared units

$$v_1 = \mathrm{vol}\,(\mathrm{chloroplast}) \cdot \mathrm{k1} \cdot [\mathrm{RuBP}] \cdot [\mathrm{CO2}] \tag{4}$$

Table 8: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.006		☑

8.2 Reaction PGA_red

This is an irreversible reaction of two reactants forming three products.

Name PGA reduction

Reaction equation

$$\mathrm{PGA} + \mathrm{ATP} \longrightarrow \mathrm{TP} + \mathrm{ADP} + \mathrm{Pi} \tag{5}$$

Reactants

Table 9: Properties of each reactant.

Id	Name	SBO
PGA	PGA	
ATP	ATP	

Products

Table 10: Properties of each product.

Id	Name	SBO
TP	TP	
ADP	ADP	
Pi	Pi	

Kinetic Law

Derived unit contains undeclared units

$$v_2 = \mathrm{vol}\,(\mathrm{chloroplast}) \cdot \mathrm{k1} \cdot [\mathrm{PGA}] \cdot [\mathrm{ATP}] \tag{6}$$

Table 11: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.021		☑

8.3 Reaction FBP_A_ase

This is a reversible reaction of one reactant forming two products.

Name FBP ald + ase

Reaction equation

$$2\,\mathrm{TP} \rightleftharpoons \mathrm{HeP} + \mathrm{Pi} \tag{7}$$

Reactant

Table 12: Properties of each reactant.

Id	Name	SBO
TP	TP	

Products

Table 13: Properties of each product.

Id	Name	SBO
HeP	HeP	
Pi	Pi	

Kinetic Law

Derived unit contains undeclared units

$$v_3 = \mathrm{vol}\,(\mathrm{chloroplast}) \cdot \left(\mathrm{k1} \cdot [\mathrm{TP}]^2 - \mathrm{k2} \cdot [\mathrm{HeP}] \cdot [\mathrm{Pi}]\right) \tag{8}$$

Table 14: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	4.0		☑
k2	k2	0000009	0.0		☑

8.4 Reaction F6P_TK1

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

Name F6P trans I

Reaction equation

$$\mathrm{HeP} \longrightarrow \mathrm{TPGA} + \mathrm{E4P} \tag{9}$$

Reactant

Table 15: Properties of each reactant.

Id	Name	SBO
HeP	HeP	

Products

Table 16: Properties of each product.

Id	Name	SBO
TPGA	TPGA	
E4P	E4P	

Kinetic Law

Derived unit contains undeclared units

$$v_4 = \mathrm{vol}\,(\mathrm{chloroplast}) \cdot \mathrm{k1} \cdot [\mathrm{HeP}] \tag{10}$$

Table 17: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.031		☑

8.5 Reaction SBP_A_ase

This is an irreversible reaction of two reactants forming two products.

Name SBP ald + ase

Reaction equation

$$\mathrm{E4P} + \mathrm{TP} \longrightarrow \mathrm{S7P} + \mathrm{Pi} \tag{11}$$

Reactants

Table 18: Properties of each reactant.

Id	Name	SBO
E4P	E4P	
TP	TP	

Products

Table 19: Properties of each product.

Id	Name	SBO
S7P	S7P	
Pi	Pi	

Kinetic Law

Derived unit contains undeclared units

$$v_5 = \mathrm{vol}\,(\mathrm{chloroplast}) \cdot \mathrm{k1} \cdot [\mathrm{E4P}] \cdot [\mathrm{TP}] \tag{12}$$

Table 20: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	3.1		☑

8.6 Reaction S7P_TK1_R5P_I

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

Name S7P trans I + R5P iso

Reaction equation

$$\mathrm{S7P} \longrightarrow \mathrm{TPGA} + \mathrm{Ru5P} \tag{13}$$

Reactant

Table 21: Properties of each reactant.

Id	Name	SBO
S7P	S7P	

Products

Table 22: Properties of each product.

Id	Name	SBO
TPGA	TPGA	
Ru5P	Ru5P	

Kinetic Law

Derived unit contains undeclared units

$$v_6 = \mathrm{vol}\,(\mathrm{chloroplast}) \cdot \mathrm{k1} \cdot [\mathrm{S7P}] \tag{14}$$

Table 23: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.31		☑

8.7 Reaction TK2_Ru5P_E

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

Name trans II + Ru5P epi

Reaction equation

$$\mathrm{TPGA} + \mathrm{TP} \longrightarrow \mathrm{Ru5P} \tag{15}$$

Reactants

Table 24: Properties of each reactant.

Id	Name	SBO
TPGA	TPGA	
TP	TP	

Product

Table 25: Properties of each product.

Id	Name	SBO
Ru5P	Ru5P	

Kinetic Law

Derived unit contains undeclared units

$$v_7 = \mathrm{vol}\,(\mathrm{chloroplast}) \cdot \mathrm{k1} \cdot [\mathrm{TPGA}] \cdot [\mathrm{TP}] \tag{16}$$

Table 26: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	6.2		☑

8.8 Reaction Ru5P_K

This is an irreversible reaction of two reactants forming two products.

Name Ru5P kinase

Reaction equation

$$\mathrm{Ru5P} + \mathrm{ATP} \longrightarrow \mathrm{RuBP} + \mathrm{ADP} \tag{17}$$

Reactants

Table 27: Properties of each reactant.

Id	Name	SBO
Ru5P	Ru5P	
ATP	ATP	

Products

Table 28: Properties of each product.

Id	Name	SBO
RuBP	RuBP	
ADP	ADP	

Kinetic Law

Derived unit contains undeclared units

$$v_8 = \mathrm{vol}\,(\mathrm{chloroplast}) \cdot \mathrm{k1} \cdot [\mathrm{Ru5P}] \cdot [\mathrm{ATP}] \tag{18}$$

Table 29: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.031		☑

8.9 Reaction ATP_S

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

Name ATP synthase

Reaction equation

$$\mathrm{ADP} + \mathrm{Pi} \longrightarrow \mathrm{ATP} \tag{19}$$

Reactants

Table 30: Properties of each reactant.

Id	Name	SBO
ADP	ADP	
Pi	Pi	

Product

Table 31: Properties of each product.

Id	Name	SBO
ATP	ATP	

Kinetic Law

Derived unit contains undeclared units

$$v_9 = \mathrm{vol}\,(\mathrm{chloroplast}) \cdot \mathrm{k1} \cdot [\mathrm{ADP}] \cdot [\mathrm{Pi}] \tag{20}$$

Table 32: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.279		☑

8.10 Reaction Starch_S

This is an irreversible reaction of two reactants forming three products.

Name starch synthetase

Reaction equation

$$\mathrm{ATP} + \mathrm{HeP} \longrightarrow \mathrm{GG} + \mathrm{ADP} + 2\,\mathrm{Pi} \tag{21}$$

Reactants

Table 33: Properties of each reactant.

Id	Name	SBO
ATP	ATP	
HeP	HeP	

Products

Table 34: Properties of each product.

Id	Name	SBO
GG	GG	
ADP	ADP	
Pi	Pi	

Kinetic Law

Derived unit contains undeclared units

$$v_{10} = \mathrm{vol}\,(\mathrm{chloroplast}) \cdot \mathrm{k1} \cdot [\mathrm{ATP}] \cdot [\mathrm{HeP}] \tag{22}$$

Table 35: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.002		☑

8.11 Reaction Starch_P

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

Name starch phosphorylase

Reaction equation

$$\mathrm{GG} + \mathrm{Pi} \longrightarrow \mathrm{HeP} \tag{23}$$

Reactants

Table 36: Properties of each reactant.

Id	Name	SBO
GG	GG	
Pi	Pi	

Product

Table 37: Properties of each product.

Id	Name	SBO
HeP	HeP	

Kinetic Law

Derived unit contains undeclared units

$$v_{11} = \mathrm{vol}\,(\mathrm{chloroplast}) \cdot \mathrm{k1} \cdot [\mathrm{GG}] \cdot [\mathrm{Pi}] \tag{24}$$

Table 38: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	$4 \cdot 10^{-5}$		☑

8.12 Reaction TPT

This is an irreversible reaction of two reactants forming two products.

Name TP translocator

Reaction equation

$$\mathrm{TP} + \mathrm{Pic} \longrightarrow \mathrm{TPc} + \mathrm{Pi} \tag{25}$$

Reactants

Table 39: Properties of each reactant.

Id	Name	SBO
TP	TP	
Pic	Pic	

Products

Table 40: Properties of each product.

Id	Name	SBO
TPc	TPc	
Pi	Pi	

Kinetic Law

Derived unit contains undeclared units

$$v_{12} = \mathrm{k1} \cdot [\mathrm{TP}] \cdot [\mathrm{Pic}] \tag{26}$$

Table 41: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.5		☑

8.13 Reaction FBPc_A_ase

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

Name FBPc ald + ase

Reaction equation

$$2\,\mathrm{TPc} \longrightarrow \mathrm{HePc} + \mathrm{Pic} \tag{27}$$

Reactant

Table 42: Properties of each reactant.

Id	Name	SBO
TPc	TPc	

Products

Table 43: Properties of each product.

Id	Name	SBO
HePc	HePc	
Pic	Pic	

Kinetic Law

Derived unit contains undeclared units

$$v_{13} = \mathrm{vol}\,(\mathrm{cytosol}) \cdot \mathrm{k1} \cdot [\mathrm{TPc}]^2 \tag{28}$$

Table 44: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	1.55		☑

8.14 Reaction Suc_S

This is an irreversible reaction of two reactants forming three products.

Name sucrose synthetase

Reaction equation

$$2\,\mathrm{HePc} + \mathrm{UTP} \longrightarrow \mathrm{Suc} + \mathrm{UDP} + 3\,\mathrm{Pic} \tag{29}$$

Reactants

Table 45: Properties of each reactant.

Id	Name	SBO
HePc	HePc	
UTP	UTP	

Products

Table 46: Properties of each product.

Id	Name	SBO
Suc	Suc	
UDP	UDP	
Pic	Pic	

Kinetic Law

Derived unit not available

$$v_{14} = \text{function\_1}\,(\text{v\_15}) \tag{30}$$

$$\text{function\_1}\,(\text{v}) = \text{v} \tag{31}$$

8.15 Reaction UTP_S

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

Name UTP synthase

Reaction equation

$$\text{UDP} + \text{Pic} \longrightarrow \text{UTP} \tag{32}$$

Reactants

Table 47: Properties of each reactant.

Id	Name	SBO
UDP	UDP	
Pic	Pic	

Product

Table 48: Properties of each product.

Id	Name	SBO
UTP	UTP	

Kinetic Law

Derived unit contains undeclared units

$$v_{15} = \mathrm{k1} \cdot [\mathrm{UDP}] \cdot [\mathrm{Pic}] \tag{33}$$

Table 49: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.008		☑

8.16 Reaction Respi

This is an irreversible reaction of one reactant forming one product.

Name respiration rate

Reaction equation

$$\mathrm{Suc} \longrightarrow \mathrm{Resp} \tag{34}$$

Reactant

Table 50: Properties of each reactant.

Id	Name	SBO
Suc	Suc	

Product

Table 51: Properties of each product.

Id	Name	SBO
Resp	Resp	

Kinetic Law

Derived unit contains undeclared units

$$v_{16} = \mathrm{r} \cdot [\mathrm{Suc}] \tag{35}$$

8.17 Reaction Diffu

This is a reversible reaction of one reactant forming one product.

Name diffusion rate

Reaction equation

$$\mathrm{Suc} \rightleftharpoons \mathrm{SucV} \tag{36}$$

Reactant

Table 52: Properties of each reactant.

Id	Name	SBO
Suc	Suc	

Product

Table 53: Properties of each product.

Id	Name	SBO
SucV	SucV	

Kinetic Law

Derived unit contains undeclared units

$$v_{17} = \mathrm{D} \cdot [\mathrm{Suc}] - \mathrm{D} \cdot [\mathrm{SucV}] \tag{37}$$

8.18 Reaction Transl

This is a reversible reaction of one reactant forming one product.

Name translocation rate

Reaction equation

$$\mathrm{Suc} \rightleftharpoons \mathrm{E} \tag{38}$$

Reactant

Table 54: Properties of each reactant.

Id	Name	SBO
Suc	Suc	

Product

Table 55: Properties of each product.

Id	Name	SBO
E	E	

Kinetic Law

Derived unit contains undeclared units

$$v_{18} = \text{phi} \cdot [\text{Suc}] - \text{phi} \cdot [\text{E}] \tag{39}$$

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 $2\ \text{mmol} \cdot \text{ml}^{-1}$

This species takes part in two reactions (as a reactant in RuBisCO and as a product in Ru5P_K).

$$\frac{\text{d}}{\text{d}t}\text{RuBP} = v_8 - v_1 \tag{40}$$

9.2 Species PGA

Name PGA

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

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

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{PGA} = 2\,v_1 - v_2 \tag{41}$$

9.3 Species TP

Name TP

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

This species takes part in five reactions (as a reactant in FBP_A_ase, SBP_A_ase, TK2_Ru5P_E, TPT and as a product in PGA_red).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{TP} = v_2 - 2\,v_3 - v_5 - v_7 - v_{12} \tag{42}$$

9.4 Species HeP

Name HeP

Initial concentration $2.2\ \mathrm{mmol} \cdot \mathrm{ml}^{-1}$

This species takes part in four reactions (as a reactant in F6P_TK1, Starch_S and as a product in FBP_A_ase, Starch_P).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{HeP} = v_3 + v_{11} - v_4 - v_{10} \tag{43}$$

9.5 Species TPGA

Name TPGA

Notes TPGA = R5P + X5P

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

This species takes part in three reactions (as a reactant in TK2_Ru5P_E and as a product in F6P-_TK1, S7P_TK1_R5P_I).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{TPGA} = v_4 + v_6 - v_7 \tag{44}$$

9.6 Species E4P

Name E4P

Initial concentration $0.05\ \mathrm{mmol \cdot ml^{-1}}$

This species takes part in two reactions (as a reactant in SBP_A_ase and as a product in F6P_TK1).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{E4P} = v_4 - v_5 \tag{45}$$

9.7 Species S7P

Name S7P

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

This species takes part in two reactions (as a reactant in S7P_TK1_R5P_I and as a product in SBP_A_ase).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{S7P} = v_5 - v_6 \tag{46}$$

9.8 Species Ru5P

Name Ru5P

Initial concentration $0.05\ \mathrm{mmol \cdot ml^{-1}}$

This species takes part in three reactions (as a reactant in Ru5P_K and as a product in S7P_TK1_R5P_I, TK2_Ru5P_E).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ru5P} = v_6 + v_7 - v_8 \tag{47}$$

9.9 Species GG

Name GG

Notes Hahn et al. (1984) Table 1

Initial concentration $99.9999999999999\ \mathrm{mmol \cdot ml^{-1}}$

This species takes part in two reactions (as a reactant in Starch_P and as a product in Starch_S).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{GG} = v_{10} - v_{11} \tag{48}$$

9.10 Species ATP

Name ATP

Notes Hahn et al. (1984) Table 1

Initial concentration $3.875\ \mathrm{mmol \cdot ml^{-1}}$

This species takes part in four reactions (as a reactant in PGA_red, Ru5P_K, Starch_S and as a product in ATP_S).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ATP} = v_9 - v_2 - v_8 - v_{10} \tag{49}$$

9.11 Species ADP

Name ADP

Notes Hahn et al. (1984) Table 1

Initial concentration $0.53\ \mathrm{mmol \cdot ml^{-1}}$

This species takes part in four reactions (as a reactant in ATP_S and as a product in PGA_red, Ru5P_K, Starch_S).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ADP} = v_2 + v_8 + v_{10} - v_9 \tag{50}$$

9.12 Species UTP

Name UTP

Notes Hahn et al. (1984) Table 1

Initial concentration $3.871\ \mathrm{mmol \cdot ml^{-1}}$

This species takes part in two reactions (as a reactant in Suc_S and as a product in UTP_S).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{UTP} = v_{15} - v_{14} \tag{51}$$

9.13 Species UDP

Name UDP

Notes Hahn et al. (1984) Table 1

Initial concentration $1.613\ \mathrm{mmol \cdot ml^{-1}}$

This species takes part in two reactions (as a reactant in UTP_S and as a product in Suc_S).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{UDP} = v_{14} - v_{15} \tag{52}$$

9.14 Species Pi

Name Pi

Notes Hahn et al. (1984) Table 1

Initial concentration $2.5\ \mathrm{mmol}\cdot\mathrm{ml}^{-1}$

This species takes part in seven reactions (as a reactant in ATP_S, Starch_P and as a product in PGA_red, FBP_A_ase, SBP_A_ase, Starch_S, TPT).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Pi} = v_2 + v_3 + v_5 + 2\,v_{10} + v_{12} - v_9 - v_{11} \tag{53}$$

9.15 Species CO2

Name CO2

Notes [Pa] Hahn et al. (1984) Table 2

Initial concentration $31\ \mathrm{mmol}\cdot\mathrm{ml}^{-1}$

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

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{CO2} = 0 \tag{54}$$

9.16 Species TPc

Name TPc

Notes Hahn et al. (1984) Table 1

Initial concentration $0.114\ \mathrm{mmol}\cdot\mathrm{ml}^{-1}$

This species takes part in two reactions (as a reactant in FBPc_A_ase and as a product in TPT).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{TPc} = v_{12} - 2\,v_{13} \tag{55}$$

9.17 Species HePc

Name HePc

Notes Hahn et al. (1984) Table 1

Initial concentration $0.1\ \mathrm{mmol}\cdot\mathrm{ml}^{-1}$

This species takes part in two reactions (as a reactant in Suc_S and as a product in FBPc_A_ase).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{HePc} = v_{13} - 2\,v_{14} \tag{56}$$

9.18 Species Suc

Name Suc

Notes Hahn et al. (1984) Table 1

Initial concentration $77.31\ \mathrm{mmol \cdot ml^{-1}}$

This species takes part in four reactions (as a reactant in Respi, Diffu, Transl and as a product in Suc_S).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Suc} = v_{14} - v_{16} - v_{17} - v_{18} \tag{57}$$

9.19 Species Pic

Name Pic

Notes Hahn et al. (1984) Table 1

Initial concentration $0.8\ \mathrm{mmol \cdot ml^{-1}}$

This species takes part in four reactions (as a reactant in TPT, UTP_S and as a product in FBPc-_A_ase, Suc_S).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Pic} = v_{13} + 3\,v_{14} - v_{12} - v_{15} \tag{58}$$

9.20 Species SucV

Name SucV

Notes Hahn et al. (1984) Table 1

Initial concentration $77.31\ \mathrm{mmol \cdot ml^{-1}}$

This species takes part in one reaction (as a product in Diffu).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{SucV} = v_{17} \tag{59}$$

9.21 Species E

Name E

SBO:0000009 kinetic constant

Notes Hahn et al. (1984) Table 2

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

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

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{E} = 0 \tag{60}$$

9.22 Species `Resp`

Name Resp

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

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

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Resp} = 0 \tag{61}$$

A Glossary of Systems Biology Ontology Terms

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

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