

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 Chelliah¹, Anne Arnold² and Zoran Nikoloski³ 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 m²

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	<input checked="" type="checkbox"/>	
cytosol	cytosol		3	1	litre	<input checked="" type="checkbox"/>	
vacuole	vacuole		3	1	litre	<input checked="" type="checkbox"/>	
phloem	phloem		3	1	litre	<input checked="" type="checkbox"/>	

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	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
PGA	PGA	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
TP	TP	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
HeP	HeP	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
TPGA	TPGA	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
E4P	E4P	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
S7P	S7P	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
Ru5P	Ru5P	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
GG	GG	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
ATP	ATP	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
ADP	ADP	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
UTP	UTP	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
UDP	UDP	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
Pi	Pi	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
CO2	CO2	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
TPc	TPc	cytosol	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
HePc	HePc	cytosol	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
Suc	Suc	cytosol	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
Pic	Pic	cytosol	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
SucV	SucV	vacuole	$\text{mmol} \cdot \text{ml}^{-1}$	<input type="checkbox"/>	<input type="checkbox"/>
E	E	phloem	$\text{mmol} \cdot \text{ml}^{-1}$	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Id	Name	Compartment	Derived Unit	Constant	Boundary Condi- tion
Resp	Resp	chloroplast	$\text{mmol} \cdot \text{ml}^{-1}$	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

5 Parameters

This model contains four global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
r	r	0000009	$3 \cdot 10^{-5}$		<input checked="" type="checkbox"/>
D	D	0000009	10^{-4}		<input checked="" type="checkbox"/>
phi	phi	0000009	10^{-4}		<input checked="" type="checkbox"/>
v_15	v(15)	0000009	0.010		<input type="checkbox"/>

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

$$v \quad (1)$$

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`:

$$v_{15} = 0.0258 \cdot [\text{HePc}] \cdot [\text{UTP}] \quad (2)$$

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

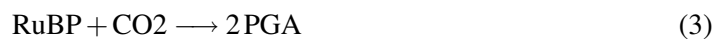
Nº	Id	Name	Reaction Equation	SBO
1	RuBisCO	RuBisCO	$\text{RuBP} + \text{CO}_2 \longrightarrow 2 \text{PGA}$	
2	PGA_red	PGA reduction	$\text{PGA} + \text{ATP} \longrightarrow \text{TP} + \text{ADP} + \text{Pi}$	
3	FBP_A_ase	FBP ald + ase	$2 \text{TP} \rightleftharpoons \text{HeP} + \text{Pi}$	
4	F6P_TK1	F6P trans I	$\text{HeP} \longrightarrow \text{TPGA} + \text{E4P}$	
5	SBP_A_ase	SBP ald + ase	$\text{E4P} + \text{TP} \longrightarrow \text{S7P} + \text{Pi}$	
6	S7P_TK1_R5P_I	S7P trans I + R5P iso	$\text{S7P} \longrightarrow \text{TPGA} + \text{Ru5P}$	
7	TK2_Ru5P_E	trans II + Ru5P epi	$\text{TPGA} + \text{TP} \longrightarrow \text{Ru5P}$	
8	Ru5P_K	Ru5P kinase	$\text{Ru5P} + \text{ATP} \longrightarrow \text{RuBP} + \text{ADP}$	
9	ATP_S	ATP synthase	$\text{ADP} + \text{Pi} \longrightarrow \text{ATP}$	
10	Starch_S	starch synthetase	$\text{ATP} + \text{HeP} \longrightarrow \text{GG} + \text{ADP} + 2 \text{Pi}$	
11	Starch_P	starch phosphorylase	$\text{GG} + \text{Pi} \longrightarrow \text{HeP}$	
12	TPT	TP translocator	$\text{TP} + \text{Pic} \longrightarrow \text{TPc} + \text{Pi}$	
13	FBPc_A_ase	FBPc ald + ase	$2 \text{TPc} \longrightarrow \text{HePc} + \text{Pic}$	
14	Suc_S	sucrose synthetase	$2 \text{HePc} + \text{UTP} \longrightarrow \text{Suc} + \text{UDP} + 3 \text{Pic}$	
15	UTP_S	UTP synthase	$\text{UDP} + \text{Pic} \longrightarrow \text{UTP}$	
16	Respi	respiration rate	$\text{Suc} \longrightarrow \text{Resp}$	
17	Diffu	diffusion rate	$\text{Suc} \rightleftharpoons \text{SucV}$	
18	Transl	translocation rate	$\text{Suc} \rightleftharpoons \text{E}$	

8.1 Reaction RuBisCO

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

Name RuBisCO

Reaction equation



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

$$v_1 = \text{vol}(\text{chloroplast}) \cdot k_1 \cdot [\text{RuBP}] \cdot [\text{CO}_2] \quad (4)$$

Table 8: Properties of each parameter.

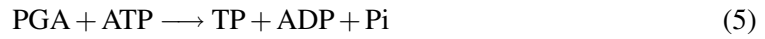
Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.006		<input checked="" type="checkbox"/>

8.2 Reaction PGA_red

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

Name PGA reduction

Reaction equation



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

$$v_2 = \text{vol}(\text{chloroplast}) \cdot k_1 \cdot [\text{PGA}] \cdot [\text{ATP}] \quad (6)$$

Table 11: Properties of each parameter.

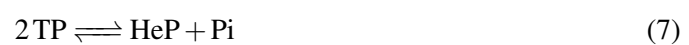
Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.021		<input checked="" type="checkbox"/>

8.3 Reaction FBP_A_ase

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

Name FBP ald + ase

Reaction equation



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

$$v_3 = \text{vol}(\text{chloroplast}) \cdot (k1 \cdot [\text{TP}]^2 - k2 \cdot [\text{HeP}] \cdot [\text{Pi}]) \quad (8)$$

Table 14: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	4.0		<input checked="" type="checkbox"/>
k2	k2	0000009	0.0		<input checked="" type="checkbox"/>

8.4 Reaction F6P_TK1

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

Name F6P trans I

Reaction equation



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

$$v_4 = \text{vol}(\text{chloroplast}) \cdot k_1 \cdot [\text{HeP}] \quad (10)$$

Table 17: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.031		<input checked="" type="checkbox"/>

8.5 Reaction SBP_A_ase

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

Name SBP ald + ase

Reaction equation



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

$$v_5 = \text{vol}(\text{chloroplast}) \cdot k_1 \cdot [\text{E4P}] \cdot [\text{TP}] \quad (12)$$

Table 20: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	3.1		<input checked="" type="checkbox"/>

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



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

$$v_6 = \text{vol}(\text{chloroplast}) \cdot k_1 \cdot [\text{S7P}] \quad (14)$$

Table 23: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.31		<input checked="" type="checkbox"/>

8.7 Reaction TK2_Ru5P_E

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

Name trans II + Ru5P epi

Reaction equation



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

$$v_7 = \text{vol}(\text{chloroplast}) \cdot k_1 \cdot [\text{TPGA}] \cdot [\text{TP}] \quad (16)$$

Table 26: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	6.2		<input checked="" type="checkbox"/>

8.8 Reaction Ru5P_K

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

Name Ru5P kinase

Reaction equation



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

$$v_8 = \text{vol}(\text{chloroplast}) \cdot k_1 \cdot [\text{Ru5P}] \cdot [\text{ATP}] \quad (18)$$

Table 29: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.031		<input checked="" type="checkbox"/>

8.9 Reaction ATP_S

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

Name ATP synthase

Reaction equation



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

$$v_9 = \text{vol}(\text{chloroplast}) \cdot k1 \cdot [\text{ADP}] \cdot [\text{Pi}] \quad (20)$$

Table 32: Properties of each parameter.

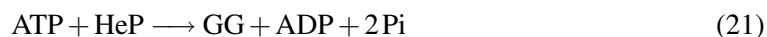
Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.279		<input checked="" type="checkbox"/>

8.10 Reaction Starch_S

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

Name starch synthetase

Reaction equation



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

$$v_{10} = \text{vol}(\text{chloroplast}) \cdot k1 \cdot [\text{ATP}] \cdot [\text{HeP}] \quad (22)$$

Table 35: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.002		<input checked="" type="checkbox"/>

8.11 Reaction Starch_P

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

Name starch phosphorylase

Reaction equation



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

$$v_{11} = \text{vol}(\text{chloroplast}) \cdot k_1 \cdot [\text{GG}] \cdot [\text{Pi}] \quad (24)$$

Table 38: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	$4 \cdot 10^{-5}$		<input checked="" type="checkbox"/>

8.12 Reaction TPT

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

Name TP translocator

Reaction equation



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

$$v_{12} = k1 \cdot [TP] \cdot [Pic] \quad (26)$$

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



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

$$v_{13} = \text{vol}(\text{cytosol}) \cdot k1 \cdot [\text{TPc}]^2 \quad (28)$$

Table 44: Properties of each parameter.

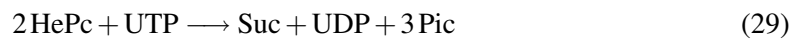
Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	1.55		<input checked="" type="checkbox"/>

8.14 Reaction Suc_S

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

Name sucrose synthetase

Reaction equation



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

$$v_{14} = \text{function_1}(v_{15}) \quad (30)$$

$$\text{function_1}(v) = v \quad (31)$$

8.15 Reaction UTP_S

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

Name UTP synthase

Reaction equation



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

$$v_{15} = k1 \cdot [\text{UDP}] \cdot [\text{Pic}] \quad (33)$$

Table 49: Properties of each parameter.

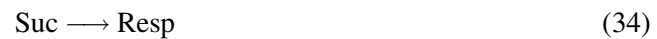
Id	Name	SBO	Value	Unit	Constant
k1	k1	0000009	0.008		✓

8.16 Reaction *Respi*

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

Name respiration rate

Reaction equation



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

$$v_{16} = r \cdot [\text{Suc}] \quad (35)$$

8.17 Reaction Diffu

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

Name diffusion rate

Reaction equation



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

$$v_{17} = D \cdot [\text{Suc}] - D \cdot [\text{SucV}]$$

(37)

8.18 Reaction Transl

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

Name translocation rate

Reaction equation



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

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

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 mmol · ml⁻¹

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

$$\frac{d}{dt} \text{RuBP} = v_8 - v_1 \quad (40)$$

9.2 Species PGA

Name PGA

Initial concentration 2.4 mmol · ml⁻¹

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

$$\frac{d}{dt}\text{PGA} = 2 v_1 - v_2 \quad (41)$$

9.3 Species TP

Name TP

Initial concentration 0.5 mmol · 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](#)).

$$\frac{d}{dt}\text{TP} = v_2 - 2 v_3 - v_5 - v_7 - v_{12} \quad (42)$$

9.4 Species HeP

Name HeP

Initial concentration 2.2 mmol · 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](#)).

$$\frac{d}{dt}\text{HeP} = v_3 + v_{11} - v_4 - v_{10} \quad (43)$$

9.5 Species TPGA

Name TPGA

Notes TPGA = R5P + X5P

Initial concentration 0.2 mmol · 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](#)).

$$\frac{d}{dt}\text{TPGA} = v_4 + v_6 - v_7 \quad (44)$$

9.6 Species E4P

Name E4P

Initial concentration 0.05 mmol · ml⁻¹

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

$$\frac{d}{dt}E4P = v_4 - v_5 \quad (45)$$

9.7 Species S7P

Name S7P

Initial concentration 2 mmol · 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](#)).

$$\frac{d}{dt}S7P = v_5 - v_6 \quad (46)$$

9.8 Species Ru5P

Name Ru5P

Initial concentration 0.05 mmol · 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](#)).

$$\frac{d}{dt}Ru5P = v_6 + v_7 - v_8 \quad (47)$$

9.9 Species GG

Name GG

Notes Hahn et al. (1984) Table 1

Initial concentration 99.999999999999 mmol · ml⁻¹

This species takes part in two reactions (as a reactant in [Starch_P](#) and as a product in [Starch-S](#)).

$$\frac{d}{dt}GG = v_{10} - v_{11} \quad (48)$$

9.10 Species ATP

Name ATP

Notes Hahn et al. (1984) Table 1

Initial concentration 3.875 mmol · 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](#)).

$$\frac{d}{dt}\text{ATP} = v_9 - v_2 - v_8 - v_{10} \quad (49)$$

9.11 Species ADP

Name ADP

Notes Hahn et al. (1984) Table 1

Initial concentration 0.53 mmol · 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](#)).

$$\frac{d}{dt}\text{ADP} = v_2 + v_8 + v_{10} - v_9 \quad (50)$$

9.12 Species UTP

Name UTP

Notes Hahn et al. (1984) Table 1

Initial concentration 3.871 mmol · ml⁻¹

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

$$\frac{d}{dt}\text{UTP} = v_{15} - v_{14} \quad (51)$$

9.13 Species UDP

Name UDP

Notes Hahn et al. (1984) Table 1

Initial concentration 1.613 mmol · ml⁻¹

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

$$\frac{d}{dt}\text{UDP} = v_{14} - v_{15} \quad (52)$$

9.14 Species Pi

Name Pi

Notes Hahn et al. (1984) Table 1

Initial concentration 2.5 mmol · 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](#)).

$$\frac{d}{dt}\text{Pi} = v_2 + v_3 + v_5 + 2v_{10} + v_{12} - v_9 - v_{11} \quad (53)$$

9.15 Species CO2

Name CO2

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

Initial concentration 31 mmol · 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:

$$\frac{d}{dt}\text{CO}_2 = 0 \quad (54)$$

9.16 Species TPc

Name TPc

Notes Hahn et al. (1984) Table 1

Initial concentration 0.114 mmol · ml⁻¹

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

$$\frac{d}{dt}\text{TPc} = v_{12} - 2v_{13} \quad (55)$$

9.17 Species HePc

Name HePc

Notes Hahn et al. (1984) Table 1

Initial concentration 0.1 mmol · ml⁻¹

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

$$\frac{d}{dt}\text{HePc} = v_{13} - 2v_{14} \quad (56)$$

9.18 Species `Suc`

Name `Suc`

Notes Hahn et al. (1984) Table 1

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

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

$$\frac{d}{dt}\text{Suc} = v_{14} - v_{16} - v_{17} - v_{18} \quad (57)$$

9.19 Species `Pic`

Name `Pic`

Notes Hahn et al. (1984) Table 1

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

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

$$\frac{d}{dt}\text{Pic} = v_{13} + 3 v_{14} - v_{12} - v_{15} \quad (58)$$

9.20 Species `SucV`

Name `SucV`

Notes Hahn et al. (1984) Table 1

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

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

$$\frac{d}{dt}\text{SucV} = v_{17} \quad (59)$$

9.21 Species `E`

Name `E`

SBO:0000009 kinetic constant

Notes Hahn et al. (1984) Table 2

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

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:

$$\frac{d}{dt}E = 0 \quad (60)$$

9.22 Species [Resp](#)

Name [Resp](#)

Initial concentration 1 mmol · 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:

$$\frac{d}{dt}\text{Resp} = 0 \quad (61)$$

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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