

## SBML Model Report

# Model name: “Levchenko2000\_MAPK\_noScaffold”



May 6, 2016

## 1 General Overview

This is a document in SBML Level 2 Version 4 format. This model was created by Bruce Shapiro<sup>1</sup> at February 15<sup>th</sup> 2005 at 0:12 a.m. and last time modified at June third 2013 at 1:36 p.m. Table 1 shows 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	22
events	0	constraints	0
reactions	30	function definitions	0
global parameters	0	unit definitions	1
rules	0	initial assignments	0

## Model Notes

### MAPK cascade in solution (no scaffold)

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#### Description

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This model describes a basic 3-stage Mitogen Activated Protein Kinase (MAPK) cascade in solution. This cascade is typically expressed as  $RAF \rightleftharpoons MEK \rightleftharpoons MAPK$  (alternative forms are  $K3 \rightleftharpoons K2 \rightleftharpoons K1$  and  $KKK \rightleftharpoons KK \rightleftharpoons K$ ). The input signal is RAFK (RAF Kinase) and the output signal is MAPKpp (doubly phosphorylated form of MAPK). RAFK phosphorylates RAF once to RAFp. RAFp, the phosphorylated form of RAF induces two phosphorylations of MEK, to MEKp and MEKpp. MEKpp, the doubly phosphorylated form of MEK, induces two phosphorylations of MAPK to MAPKp and MAPKpp.

Rateconstant	Reaction
a10=5.	MAPKPH+MAPKpp->MAPKppMAPKPH
a1=1.	RAF+RAFK->RAFRFK
a2=0.5	RAFp+RAFPH->RAFpRAFPH
a3=3.3	MEK+RAFp->MEKRAFp
a4=10.	MEKp+MEKPH->MEKpMEKPH
a5=3.3	MEKp+RAFp->MEKpRAFp
a6=10.	MEKPH+MEKpp->MEKppMEKPH
a7=20.	MAPK+MEKpp->MAPKMEKpp
a8=5.	MAPKp+MAPKPH->MAPKpMAPKPH
a9=20.	MAPKp+MEKpp->MAPKpMEKpp
d10=0.4	MAPKppMAPKPH->MAPKPH+MAPKpp
d1=0.4	RAFRFK->RAF+RAFK
d2=0.5	RAFpRAFPH->RAFp+RAFPH
d3=0.42	MEKRAFp->MEK+RAFp
d4=0.8	MEKpMEKPH->MEKp+MEKPH
d5=0.4	MEKpRAFp->MEKp+RAFp
d6=0.8	MEKppMEKPH->MEKPH+MEKpp
d7=0.6	MAPKMEKpp->MAPK+MEKpp
d8=0.4	MAPKpMAPKPH->MAPKp+MAPKPH
d9=0.6	MAPKpMEKpp->MAPKp+MEKpp
k10=0.1	MAPKppMAPKPH->MAPKp+MAPKPH
k1=0.1	RAFRFK->RAFK+RAFp
k2=0.1	RAFpRAFPH->RAF+RAFPH
k3=0.1	MEKRAFp->MEKp+RAFp
k4=0.1	MEKpMEKPH->MEK+MEKPH
k5=0.1	MEKpRAFp->MEKpp+RAFp
k6=0.1	MEKppMEKPH->MEKp+MEKPH
k7=0.1	MAPKMEKpp->MAPKp+MEKpp
k8=0.1	MAPKpMAPKPH->MAPK+MAPKPH

$k9=0.1$ 

MAPKpMEKpp-&gt;MAPKpp+MEKpp

Variable	IC	ODE
MAPK	0.3	$\text{MAPK}'[t] = d7 * \text{MAPKMEKpp}[t] + k8 * \text{MAPKpMA}$ $a7 * \text{MAPK}[t] * \text{MEKpp}[t]$
MAPKMEKpp	0	$\text{MAPKMEKpp}'[t] = -$ $(d7 * \text{MAPKMEKpp}[t]) -$ $k7 * \text{MAPKMEKpp}[t] + a7 * \text{MAPK}[t] * \text{MEKpp}[t]$
MAPKp	0	$\text{MAPKp}'[t] = k7 * \text{MAPKMEKpp}[t] -$ $a8 * \text{MAPKp}[t] * \text{MAPKPH}[t] + d8 * \text{MAPKpMAPKPH}$ $a9 * \text{MAPKp}[t] * \text{MEKpp}[t]$
MAPKPH	0.3	$\text{MAPKPH}'[t] = -$ $(a8 * \text{MAPKp}[t] * \text{MAPKPH}[t]) + d8 * \text{MAPKpMAPK}$ $a10 * \text{MAPKPH}[t] * \text{MAPKpp}[t] + d10 * \text{MAPKppMA}$
MAPKpMAPKPH	0	$\text{MAPKpMAPKPH}'[t] = a8 * \text{MAPKp}[t] * \text{MAPKPH}$ $d8 * \text{MAPKpMAPKPH}[t] -$ $k8 * \text{MAPKpMAPKPH}[t]$
MAPKpMEKpp	0	$\text{MAPKpMEKpp}'[t] = -$ $(d9 * \text{MAPKpMEKpp}[t]) -$ $k9 * \text{MAPKpMEKpp}[t] + a9 * \text{MAPKp}[t] * \text{MEKpp}[t]$
MAPKpp	0	$\text{MAPKpp}'[t] = k9 * \text{MAPKpMEKpp}[t] -$ $a10 * \text{MAPKPH}[t] * \text{MAPKpp}[t] + d10 * \text{MAPKppMA}$
MAPKppMAPKPH	0	$\text{MAPKppMAPKPH}'[t] = a10 * \text{MAPKPH}[t] * \text{MAPK}$ $d10 * \text{MAPKppMAPKPH}[t] -$ $k10 * \text{MAPKppMAPKPH}[t]$
MEK	0.2	$\text{MEK}'[t] = k4 * \text{MEKpMEKPH}[t] + d3 * \text{MEKRAFp}[t]$ $a3 * \text{MEK}[t] * \text{RAFp}[t]$
MEKp	0	$\text{MEKp}'[t] = -$ $(a4 * \text{MEKp}[t] * \text{MEKPH}[t]) + d4 * \text{MEKpMEKPH}[t] +$ $a5 * \text{MEKp}[t] * \text{RAFp}[t]$
MEKPH	0.2	$\text{MEKPH}'[t] = -$ $(a4 * \text{MEKp}[t] * \text{MEKPH}[t]) + d4 * \text{MEKpMEKPH}[t] +$ $a6 * \text{MEKPH}[t] * \text{MEKpp}[t] + d6 * \text{MEKppMEKPH}[t] -$
MEKpMEKPH	0	$\text{MEKpMEKPH}'[t] = a4 * \text{MEKp}[t] * \text{MEKPH}[t] -$ $d4 * \text{MEKpMEKPH}[t] -$ $k4 * \text{MEKpMEKPH}[t]$
MEKpp	0	$\text{MEKpp}'[t] = d7 * \text{MAPKMEKpp}[t] + k7 * \text{MAPKME}$ $a7 * \text{MAPK}[t] * \text{MEKpp}[t] -$ $a9 * \text{MAPKp}[t] * \text{MEKpp}[t] -$ $a6 * \text{MEKPH}[t] * \text{MEKpp}[t] + d6 * \text{MEKppMEKPH}[t] -$

MEKppMEKPH	0	$MEKppMEKPH'[t] == a6 * MEKPH[t] * MEKpp[t] - d6 * MEKppMEKPH[t] - k6 * MEKppMEKPH[t]$
MEKpRAFp	0	$MEKpRAFp'[t] == - (d5 * MEKpRAFp[t]) - k5 * MEKpRAFp[t] + a5 * MEKp[t] * RAFp[t]$
MEKRAFp	0	$MEKRAFp'[t] == - (d3 * MEKRAFp[t]) - k3 * MEKRAFp[t] + a3 * MEK[t] * RAFp[t]$
RAF	0.4	$RAF'[t] == - (a1 * RAF[t] * RAFK[t]) + k2 * RAFpRAFPH[t] + d1 * R$
RAFK	0.1	$RAFK'[t] == - (a1 * RAF[t] * RAFK[t]) + d1 * RAFRAFK[t] + k1 * R$
RAFp	0	$RAFp'[t] == d5 * MEKpRAFp[t] + k5 * MEKpRAFp[t] - a3 * MEK[t] * RAFp[t] - a5 * MEKp[t] * RAFp[t] - a2 * RAFp[t] * RAFPH[t] + d2 * RAFpRAFPH[t] + k1 * R$
RAFPH	0.3	$RAFPH'[t] == - (a2 * RAFp[t] * RAFPH[t]) + d2 * RAFpRAFPH[t] + k2$
RAFpRAFPH	0	$RAFpRAFPH'[t] == a2 * RAFp[t] * RAFPH[t] - d2 * RAFpRAFPH[t] - k2 * RAFpRAFPH[t]$
RAFRAFK	0	$RAFRAFK'[t] == a1 * RAF[t] * RAFK[t] - d1 * RAFRAFK[t] - k1 * RAFRAFK[t]$

Generated by Cellerator Version 1.4.3 (6-March-2004) using Mathematica 5.0 for Mac OS X (November 19, 2003), March 6, 2004 12:18:07, using (PowerMac,PowerPC,Mac OS X,MacOSX,Darwin) author=B.E.Shapiro

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## 2 Unit Definitions

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

## 2.1 Unit substance

**Name** micromole

**Definition**  $\mu\text{mol}$

## 2.2 Unit volume

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

**Definition** l

## 2.3 Unit area

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

**Definition**  $\text{m}^2$

## 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 Compartment

This model contains one compartment.

Table 5: Properties of all compartments.

Id	Name	SBO	Spatial Dimensions	Size	Unit	Constant	Outside
Cytoplasm			3	1	litre	<input checked="" type="checkbox"/>	

## 3.1 Compartment Cytoplasm

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

## 4 Species

This model contains 22 species. Section 6 provides further details and the derived rates of change of each species.

Table 6: Properties of each species.

Id	Name	Compartment	Derived Unit	Constant	Boundary Condition
MAPK	MAPK	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MAPKMEKpp	MAPK_MEK-PP	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MAPKp	MAPK-P	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MAPKPH	MAPK phosphatase	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MAPKpMAPKPH	MAPK-P_MAPKPase	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MAPKpMEKpp	MAPK-P_MEK-PP	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MAPKpp	MAPK-PP	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MAPKppMAPKPH	MAPK-PP_MAPKPase	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MEK	MEK	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MEKp	MEK-P	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MEKPH	MEK phosphatase	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MEKpMEKPH	MEK-P_MEKPase	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MEKpp	MEK-PP	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MEKppMEKPH	MEK-PP_MEKPase	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MEKpRAFp	MEK-P_RAF-P	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
MEKRAFp	MEK_RAF-P	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
RAF	RAF	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
RAFK	RAFK	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
RAFp	RAF-P	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
RAFPH	RAF phosphatase	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
RAFpRAFPH	RAF-P_RAFPase	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$
RAFRAFK	RAF_RAFK	Cytoplasm	$\mu\text{mol}$	$\square$	$\square$

Id	Name	Compartment	Derived Unit	Constant	Boundary Condi- tion
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## 5 Reactions

This model contains 30 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 7: Overview of all reactions

Nº	Id	Name	Reaction Equation	SBO
1	Reaction1	binding of RAF and RAFK	$\text{RAF} + \text{RAFK} \longrightarrow \text{RAFRAFK}$	
2	Reaction2	dissociation of RAF_RAFK	$\text{RAFRAFK} \longrightarrow \text{RAF} + \text{RAFK}$	
3	Reaction3	phosphorylation of RAF	$\text{RAFRAFK} \longrightarrow \text{RAFK} + \text{RAFp}$	
4	Reaction4	binding of RAF-P and RAF phosphatase	$\text{RAFp} + \text{RAFPH} \longrightarrow \text{RAFpRAFPH}$	
5	Reaction5	dissociation of RAF-P_RAFFase	$\text{RAFpRAFPH} \longrightarrow \text{RAFp} + \text{RAFPH}$	
6	Reaction6	dephosphorylation of RAF-P	$\text{RAFpRAFPH} \longrightarrow \text{RAF} + \text{RAFPH}$	
7	Reaction7	binding of MEK and RAF-P	$\text{MEK} + \text{RAFp} \longrightarrow \text{MEKRAFp}$	
8	Reaction8	dissociation of MEK_RAF-P	$\text{MEKRAFp} \longrightarrow \text{MEK} + \text{RAFp}$	
9	Reaction9	phosphorylation of MEK	$\text{MEKRAFp} \longrightarrow \text{MEKp} + \text{RAFp}$	
10	Reaction10	binding of MEK-P and MEK phosphatase	$\text{MEKp} + \text{MEKPH} \longrightarrow \text{MEKpMEKPH}$	
11	Reaction11	dissociation of MEK-P_MEKPase	$\text{MEKpMEKPH} \longrightarrow \text{MEKp} + \text{MEKPH}$	
12	Reaction12	dephosphorylation of MEK-P	$\text{MEKpMEKPH} \longrightarrow \text{MEK} + \text{MEKPH}$	
13	Reaction13	binding of MEK-P and RAF-P	$\text{MEKp} + \text{RAFp} \longrightarrow \text{MEKpRAFp}$	
14	Reaction14	dissociation of MEK-P_RAF-P	$\text{MEKpRAFp} \longrightarrow \text{MEKp} + \text{RAFp}$	
15	Reaction15	phosphorylation of MEK-P	$\text{MEKpRAFp} \longrightarrow \text{MEKpp} + \text{RAFp}$	
16	Reaction16	binding of MEK-PP and MEK phosphatase	$\text{MEKPH} + \text{MEKpp} \longrightarrow \text{MEKppMEKPH}$	
17	Reaction17	dissociation of MEK-PP_MEKPase	$\text{MEKppMEKPH} \longrightarrow \text{MEKPH} + \text{MEKpp}$	
18	Reaction18	dephosphorylation of MEK-PP	$\text{MEKppMEKPH} \longrightarrow \text{MEKp} + \text{MEKPH}$	
19	Reaction19	binding of MAPK and MEK-PP	$\text{MAPK} + \text{MEKpp} \longrightarrow \text{MAPKMEKpp}$	
20	Reaction20	dissociation of MAPK_MEK-PP	$\text{MAPKMEKpp} \longrightarrow \text{MAPK} + \text{MEKpp}$	
21	Reaction21	phosphorylation of MAPK	$\text{MAPKMEKpp} \longrightarrow \text{MAPKp} + \text{MEKpp}$	
22	Reaction22	binding of MAPK-P and MAPK phosphatase	$\text{MAPKp} + \text{MAPKPH} \longrightarrow \text{MAPKpMAPKPH}$	
23	Reaction23	dissociation of MAPK-P_MAPKPase	$\text{MAPKpMAPKPH} \longrightarrow \text{MAPKp} + \text{MAPKPH}$	



Nº	Id	Name	Reaction Equation	SBO
24	Reaction24	dephosphorylation of MAPK-P	$\text{MAPKpMAPKPH} \longrightarrow \text{MAPK} + \text{MAPKPH}$	
25	Reaction25	binding of MAPK-P and MEK-PP	$\text{MAPKp} + \text{MEKpp} \longrightarrow \text{MAPKpMEKpp}$	
26	Reaction26	dissociation of MAPK-P_MEK-PP	$\text{MAPKpMEKpp} \longrightarrow \text{MAPKp} + \text{MEKpp}$	
27	Reaction27	phosphorylation of MAPK-P	$\text{MAPKpMEKpp} \longrightarrow \text{MAPKpp} + \text{MEKpp}$	
28	Reaction28	binding of MAPK-PP and MAPK phosphatase	$\text{MAPKPH} + \text{MAPKpp} \longrightarrow \text{MAPKppMAPKPH}$	
29	Reaction29	dissociation of MAPK-PP_MAPKpase	$\text{MAPKppMAPKPH} \longrightarrow \text{MAPKPH} + \text{MAPKpp}$	
30	Reaction30	dephosphorylation of MAPK-PP	$\text{MAPKppMAPKPH} \longrightarrow \text{MAPKp} + \text{MAPKPH}$	

## 5.1 Reaction `Reaction1`

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

**Name** binding of RAF and RAFK

### Reaction equation



### Reactants

Table 8: Properties of each reactant.

Id	Name	SBO
RAF	RAF	
RAFK	RAFK	

### Product

Table 9: Properties of each product.

Id	Name	SBO
RAFRAFK	RAF_RAFK	

### Kinetic Law

**Derived unit** contains undeclared units

$$v_1 = a_1 \cdot \text{RAF} \cdot \text{RAFK} \quad (2)$$

Table 10: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
a1			1.0		<input checked="" type="checkbox"/>

## 5.2 Reaction `Reaction2`

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

**Name** dissociation of RAF\_RAFK

## Reaction equation



## Reactant

Table 11: Properties of each reactant.

Id	Name	SBO
RAFRAFK	RAF_RAFK	

## Products

Table 12: Properties of each product.

Id	Name	SBO
RAF	RAF	
RAFK	RAFK	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_2 = d1 \cdot \text{RAFRAFK} \quad (4)$$

Table 13: Properties of each parameter.

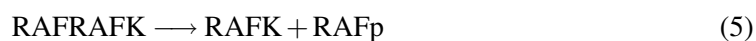
Id	Name	SBO	Value	Unit	Constant
d1			0.4		<input checked="" type="checkbox"/>

## 5.3 Reaction `Reaction3`

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

**Name** phosphorylation of RAF

## Reaction equation



## Reactant

Table 14: Properties of each reactant.

Id	Name	SBO
RAFRAFK	RAF_RAFK	

## Products

Table 15: Properties of each product.

Id	Name	SBO
RAFK	RAFK	
RAFp	RAF-P	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_3 = k1 \cdot \text{RAFRAFK} \quad (6)$$

Table 16: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k1			0.1		<input checked="" type="checkbox"/>

## 5.4 Reaction `Reaction4`

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

**Name** binding of RAF-P and RAF phosphatase

### Reaction equation



## Reactants

Table 17: Properties of each reactant.

Id	Name	SBO
RAFp	RAF-P	
RAFPH	RAF phosphatase	

## Product

Table 18: Properties of each product.

Id	Name	SBO
RAFpRAFPH	RAF-P_RAFFase	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_4 = a2 \cdot \text{RAFp} \cdot \text{RAFPH} \quad (8)$$

Table 19: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
a2			0.5		<input checked="" type="checkbox"/>

## 5.5 Reaction `Reaction5`

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

**Name** dissociation of RAF-P\_RAFFase

### Reaction equation



## Reactant

Table 20: Properties of each reactant.

Id	Name	SBO
RAFpRAFPH	RAF-P_RAFFase	

## Products

Table 21: Properties of each product.

Id	Name	SBO
RAFp	RAF-P	

Id	Name	SBO
RAFPH	RAF phosphatase	

### Kinetic Law

**Derived unit** contains undeclared units

$$v_5 = d2 \cdot \text{RAFpRAFPH} \quad (10)$$

Table 22: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
d2			0.5		<input checked="" type="checkbox"/>

### 5.6 Reaction `Reaction6`

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

**Name** dephosphorylation of RAF-P

#### Reaction equation



#### Reactant

Table 23: Properties of each reactant.

Id	Name	SBO
RAFpRAFPH	RAF-P_RAfPase	

#### Products

Table 24: Properties of each product.

Id	Name	SBO
RAF	RAF	
RAFPH	RAF phosphatase	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_6 = k_2 \cdot \text{RAFpRAFPH} \quad (12)$$

Table 25: Properties of each parameter.

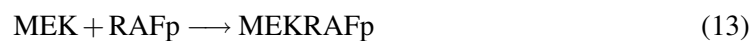
Id	Name	SBO	Value	Unit	Constant
k2			0.1		<input checked="" type="checkbox"/>

## 5.7 Reaction `Reaction7`

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

**Name** binding of MEK and RAF-P

### Reaction equation



### Reactants

Table 26: Properties of each reactant.

Id	Name	SBO
MEK	MEK	
RAFp	RAF-P	

### Product

Table 27: Properties of each product.

Id	Name	SBO
MEKRAFp	MEK_RAF-P	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_7 = a_3 \cdot \text{MEK} \cdot \text{RAFp} \quad (14)$$

Table 28: Properties of each parameter.

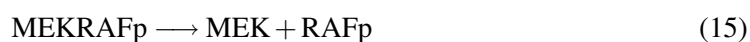
Id	Name	SBO	Value	Unit	Constant
a3			3.3		<input checked="" type="checkbox"/>

## 5.8 Reaction `Reaction8`

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

**Name** dissociation of MEK\_RAF-P

### Reaction equation



### Reactant

Table 29: Properties of each reactant.

Id	Name	SBO
MEKRAFp	MEK_RAF-P	

### Products

Table 30: Properties of each product.

Id	Name	SBO
MEK	MEK	
RAFp	RAF-P	

### Kinetic Law

**Derived unit** contains undeclared units

$$v_8 = d3 \cdot \text{MEKRAFp} \quad (16)$$

Table 31: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
d3			0.42		<input checked="" type="checkbox"/>

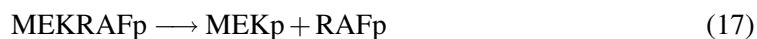


## 5.9 Reaction `Reaction9`

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

**Name** phosphorylation of MEK

### Reaction equation



### Reactant

Table 32: Properties of each reactant.

Id	Name	SBO
MEKRAFp	MEK_RAF-P	

### Products

Table 33: Properties of each product.

Id	Name	SBO
MEKp	MEK-P	
RAFp	RAF-P	

### Kinetic Law

**Derived unit** contains undeclared units

$$v_9 = k3 \cdot \text{MEKRAFp} \quad (18)$$

Table 34: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k3			0.1		<input checked="" type="checkbox"/>

## 5.10 Reaction `Reaction10`

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

**Name** binding of MEK-P and MEK phosphatase

## Reaction equation



## Reactants

Table 35: Properties of each reactant.

Id	Name	SBO
MEKp	MEK-P	
MEKPH	MEK phosphatase	

## Product

Table 36: Properties of each product.

Id	Name	SBO
MEKpMEKPH	MEK-P_MEKpase	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_{10} = a4 \cdot \text{MEKp} \cdot \text{MEKPH} \quad (20)$$

Table 37: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
a4			10.0		<input checked="" type="checkbox"/>

### 5.11 Reaction `Reaction11`

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

**Name** dissociation of MEK-P\_MEKpase

## Reaction equation



## Reactant

Table 38: Properties of each reactant.

Id	Name	SBO
MEKpMEKPH	MEK-P_MEKPase	

## Products

Table 39: Properties of each product.

Id	Name	SBO
MEKp	MEK-P	
MEKPH	MEK phosphatase	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_{11} = d4 \cdot \text{MEKpMEKPH} \quad (22)$$

Table 40: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
d4			0.8		<input checked="" type="checkbox"/>

### 5.12 Reaction [Reaction12](#)

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

**Name** dephosphorylation of MEK-P

#### Reaction equation



#### Reactant

Table 41: Properties of each reactant.

Id	Name	SBO
MEKpMEKPH	MEK-P_MEKPase	

## Products

Table 42: Properties of each product.

Id	Name	SBO
MEK	MEK	
MEKPH	MEK phosphatase	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_{12} = k4 \cdot \text{MEKpMEKPH} \quad (24)$$

Table 43: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k4			0.1		<input checked="" type="checkbox"/>

### 5.13 Reaction `Reaction13`

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

**Name** binding of MEK-P and RAF-P

#### Reaction equation



## Reactants

Table 44: Properties of each reactant.

Id	Name	SBO
MEKp	MEK-P	
RAFp	RAF-P	

## Product

Table 45: Properties of each product.

Id	Name	SBO
MEKpRAFp	MEK-P_RAF-P	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_{13} = a5 \cdot \text{MEKp} \cdot \text{RAFp} \quad (26)$$

Table 46: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
a5			3.3		<input checked="" type="checkbox"/>

## 5.14 Reaction `Reaction14`

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

**Name** dissociation of MEK-P\_RAF-P

### Reaction equation



### Reactant

Table 47: Properties of each reactant.

Id	Name	SBO
MEKpRAFp	MEK-P_RAF-P	

### Products

Table 48: Properties of each product.

Id	Name	SBO
MEKp	MEK-P	
RAFp	RAF-P	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_{14} = d5 \cdot \text{MEKpRAFp} \quad (28)$$

Table 49: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
d5			0.4		<input checked="" type="checkbox"/>

## 5.15 Reaction `Reaction15`

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

**Name** phosphorylation of MEK-P

### Reaction equation



### Reactant

Table 50: Properties of each reactant.

Id	Name	SBO
MEKpRAFp	MEK-P_RAF-P	

### Products

Table 51: Properties of each product.

Id	Name	SBO
MEKpp	MEK-PP	
RAFp	RAF-P	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_{15} = k5 \cdot \text{MEKpRAFp} \quad (30)$$

Table 52: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k5			0.1		<input checked="" type="checkbox"/>

### 5.16 Reaction `Reaction16`

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

**Name** binding of MEK-PP and MEK phosphatase

#### Reaction equation



#### Reactants

Table 53: Properties of each reactant.

Id	Name	SBO
MEKPH	MEK phosphatase	
MEKpp	MEK-PP	

#### Product

Table 54: Properties of each product.

Id	Name	SBO
MEKppMEKPH	MEK-PP_MEKPhase	

#### Kinetic Law

**Derived unit** contains undeclared units

$$v_{16} = a_6 \cdot \text{MEKPH} \cdot \text{MEKpp} \quad (32)$$

Table 55: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
a6			10.0		<input checked="" type="checkbox"/>

### 5.17 Reaction [Reaction17](#)

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

**Name** dissociation of MEK-PP\_MEKPase

#### Reaction equation



#### Reactant

Table 56: Properties of each reactant.

Id	Name	SBO
MEKppMEKPH	MEK-PP_MEKPase	

#### Products

Table 57: Properties of each product.

Id	Name	SBO
MEKPH	MEK phosphatase	
MEKpp	MEK-PP	

#### Kinetic Law

**Derived unit** contains undeclared units

$$v_{17} = d6 \cdot \text{MEKppMEKPH} \quad (34)$$

Table 58: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
d6			0.8		<input checked="" type="checkbox"/>

### 5.18 Reaction [Reaction18](#)

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

**Name** dephosphorylation of MEK-PP



### Reaction equation



### Reactant

Table 59: Properties of each reactant.

Id	Name	SBO
MEKppMEKPH	MEK-PP_MEKPase	

### Products

Table 60: Properties of each product.

Id	Name	SBO
MEKp	MEK-P	
MEKPH	MEK phosphatase	

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{18} = k6 \cdot \text{MEKppMEKPH} \quad (36)$$

Table 61: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k6			0.1		<input checked="" type="checkbox"/>

### 5.19 Reaction `Reaction19`

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

**Name** binding of MAPK and MEK-PP

### Reaction equation



### Reactants

Table 62: Properties of each reactant.

Id	Name	SBO
MAPK	MAPK	
MEKpp	MEK-PP	

## Product

Table 63: Properties of each product.

Id	Name	SBO
MAPKMEKpp	MAPK_MEK-PP	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_{19} = a7 \cdot \text{MAPK} \cdot \text{MEKpp} \quad (38)$$

Table 64: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
a7			20.0		<input checked="" type="checkbox"/>

## 5.20 Reaction [Reaction20](#)

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

**Name** dissociation of MAPK\_MEK-PP

### Reaction equation



## Reactant

Table 65: Properties of each reactant.

Id	Name	SBO
MAPKMEKpp	MAPK_MEK-PP	

## Products

Table 66: Properties of each product.

Id	Name	SBO
MAPK	MAPK	
MEKpp	MEK-PP	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_{20} = d7 \cdot \text{MAPKMEKpp} \quad (40)$$

Table 67: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
d7			0.6		<input checked="" type="checkbox"/>

### 5.21 Reaction [Reaction21](#)

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

**Name** phosphorylation of MAPK

#### Reaction equation



#### Reactant

Table 68: Properties of each reactant.

Id	Name	SBO
MAPKMEKpp	MAPK_MEK-PP	

## Products

Table 69: Properties of each product.

Id	Name	SBO
MAPKp	MAPK-P	
MEKpp	MEK-PP	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_{21} = k7 \cdot \text{MAPKMEKpp} \quad (42)$$

Table 70: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k7			0.1		<input checked="" type="checkbox"/>

## 5.22 Reaction [Reaction22](#)

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

**Name** binding of MAPK-P and MAPK phosphatase

### Reaction equation



### Reactants

Table 71: Properties of each reactant.

Id	Name	SBO
MAPKp	MAPK-P	
MAPKPH	MAPK phosphatase	

### Product

Table 72: Properties of each product.

Id	Name	SBO
MAPKpMAPKPH	MAPK-P_MAPKpase	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_{22} = a8 \cdot \text{MAPKp} \cdot \text{MAPKPH} \quad (44)$$

Table 73: Properties of each parameter.

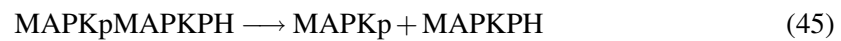
Id	Name	SBO	Value	Unit	Constant
a8			5.0		<input checked="" type="checkbox"/>

## 5.23 Reaction `Reaction23`

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

**Name** dissociation of MAPK-P.`MAPKase`

### Reaction equation



### Reactant

Table 74: Properties of each reactant.

Id	Name	SBO
<code>MAPKpMAPKPH</code>	<code>MAPK-P_MAPKase</code>	

### Products

Table 75: Properties of each product.

Id	Name	SBO
<code>MAPKp</code>	<code>MAPK-P</code>	
<code>MAPKPH</code>	<code>MAPK phosphatase</code>	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_{23} = d8 \cdot \text{MAPKpMAPKPH} \quad (46)$$

Table 76: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
d8			0.4		<input checked="" type="checkbox"/>

## 5.24 Reaction `Reaction24`

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

**Name** dephosphorylation of MAPK-P

### Reaction equation



### Reactant

Table 77: Properties of each reactant.

Id	Name	SBO
MAPKpMAPKPH	MAPK-P_MAPKase	

### Products

Table 78: Properties of each product.

Id	Name	SBO
MAPK	MAPK	
MAPKPH	MAPK phosphatase	

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{24} = k8 \cdot \text{MAPKpMAPKPH} \quad (48)$$

Table 79: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k8			0.1		<input checked="" type="checkbox"/>

## 5.25 Reaction [Reaction25](#)

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

**Name** binding of MAPK-P and MEK-PP

### Reaction equation



### Reactants

Table 80: Properties of each reactant.

Id	Name	SBO
MAPKp	MAPK-P	
MEKpp	MEK-PP	

### Product

Table 81: Properties of each product.

Id	Name	SBO
MAPKpMEKpp	MAPK-P_MEK-PP	

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{25} = a9 \cdot \text{MAPKp} \cdot \text{MEKpp} \quad (50)$$

Table 82: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
a9			20.0		<input checked="" type="checkbox"/>

## 5.26 Reaction [Reaction26](#)

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

**Name** dissociation of MAPK-P\_MEK-PP

### Reaction equation



### Reactant

Table 83: Properties of each reactant.

Id	Name	SBO
MAPKpMEKpp	MAPK-P_MEK-PP	

### Products

Table 84: Properties of each product.

Id	Name	SBO
MAPKp	MAPK-P	
MEKpp	MEK-PP	

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{26} = d9 \cdot \text{MAPKpMEKpp} \quad (52)$$

Table 85: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
d9			0.6		<input checked="" type="checkbox"/>

### 5.27 Reaction [Reaction27](#)

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

**Name** phosphorylation of MAPK-P

### Reaction equation



### Reactant



Table 86: Properties of each reactant.

Id	Name	SBO
MAPKpMEKpp	MAPK-P_MEK-PP	

## Products

Table 87: Properties of each product.

Id	Name	SBO
MAPKpp	MAPK-PP	
MEKpp	MEK-PP	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_{27} = k_9 \cdot \text{MAPKpMEKpp} \quad (54)$$

Table 88: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k9			0.1		<input checked="" type="checkbox"/>

### 5.28 Reaction `Reaction28`

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

**Name** binding of MAPK-PP and MAPK phosphatase

#### Reaction equation



## Reactants

Table 89: Properties of each reactant.

Id	Name	SBO
MAPKPH	MAPK phosphatase	
MAPKpp	MAPK-PP	

## Product

Table 90: Properties of each product.

Id	Name	SBO
MAPKppMAPKPH	MAPK-PP_MAPKPase	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_{28} = a_{10} \cdot \text{MAPKPH} \cdot \text{MAPKpp} \quad (56)$$

Table 91: Properties of each parameter.

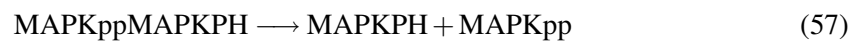
Id	Name	SBO	Value	Unit	Constant
a10			5.0		<input checked="" type="checkbox"/>

## 5.29 Reaction [Reaction29](#)

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

**Name** dissociation of MAPK-PP\_MAPKPase

### Reaction equation



## Reactant

Table 92: Properties of each reactant.

Id	Name	SBO
MAPKppMAPKPH	MAPK-PP_MAPKPase	

## Products

Table 93: Properties of each product.

Id	Name	SBO
MAPKPH	MAPK phosphatase	

Id	Name	SBO
MAPKpp	MAPK-PP	

### Kinetic Law

**Derived unit** contains undeclared units

$$v_{29} = d10 \cdot \text{MAPKppMAPKPH} \quad (58)$$

Table 94: Properties of each parameter.

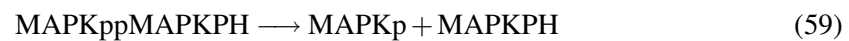
Id	Name	SBO	Value	Unit	Constant
d10			0.4		<input checked="" type="checkbox"/>

### 5.30 Reaction [Reaction30](#)

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

**Name** dephosphorylation of MAPK-PP

### Reaction equation



### Reactant

Table 95: Properties of each reactant.

Id	Name	SBO
MAPKppMAPKPH	MAPK-PP_MAPKPase	

### Products

Table 96: Properties of each product.

Id	Name	SBO
MAPKp	MAPK-P	
MAPKPH	MAPK phosphatase	

## Kinetic Law

**Derived unit** contains undeclared units

$$v_{30} = k_{10} \cdot \text{MAPKppMAPKPH} \quad (60)$$

Table 97: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
k10			0.1		<input checked="" type="checkbox"/>

## 6 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.

### 6.1 Species MAPK

**Name** MAPK

**Initial amount** 0.4  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction19](#) and as a product in [Reaction20](#), [Reaction24](#)).

$$\frac{d}{dt}\text{MAPK} = v_{20} + v_{24} - v_{19} \quad (61)$$

### 6.2 Species MAPKMEKpp

**Name** MAPK\_MEK-PP

**Initial amount** 0  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction20](#), [Reaction21](#) and as a product in [Reaction19](#)).

$$\frac{d}{dt}\text{MAPKMEKpp} = v_{19} - v_{20} - v_{21} \quad (62)$$

### 6.3 Species MAPKp

**Name** MAPK-P

**Initial amount** 0  $\mu\text{mol}$

This species takes part in six reactions (as a reactant in [Reaction22](#), [Reaction25](#) and as a product in [Reaction21](#), [Reaction23](#), [Reaction26](#), [Reaction30](#)).

$$\frac{d}{dt}\text{MAPKp} = v_{21} + v_{23} + v_{26} + v_{30} - v_{22} - v_{25} \quad (63)$$

### 6.4 Species MAPKPH

**Name** MAPK phosphatase

**Initial amount** 0.3  $\mu\text{mol}$

This species takes part in six reactions (as a reactant in [Reaction22](#), [Reaction28](#) and as a product in [Reaction23](#), [Reaction24](#), [Reaction29](#), [Reaction30](#)).

$$\frac{d}{dt}\text{MAPKPH} = v_{23} + v_{24} + v_{29} + v_{30} - v_{22} - v_{28} \quad (64)$$

### 6.5 Species MAPKpMAPKPH

**Name** MAPK-P\_MAPKPase

**Initial amount** 0  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction23](#), [Reaction24](#) and as a product in [Reaction22](#)).

$$\frac{d}{dt}\text{MAPKpMAPKPH} = v_{22} - v_{23} - v_{24} \quad (65)$$

### 6.6 Species MAPKpMEKpp

**Name** MAPK-P\_MEK-PP

**Initial amount** 0  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction26](#), [Reaction27](#) and as a product in [Reaction25](#)).

$$\frac{d}{dt}\text{MAPKpMEKpp} = v_{25} - v_{26} - v_{27} \quad (66)$$

## 6.7 Species MAPKpp

**Name** MAPK-PP

**Initial amount** 0  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction28](#) and as a product in [Reaction27](#), [Reaction29](#)).

$$\frac{d}{dt}\text{MAPKpp} = v_{27} + v_{29} - v_{28} \quad (67)$$

## 6.8 Species MAPKppMAPKPH

**Name** MAPK-PP\_MAPKPase

**Initial amount** 0  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction29](#), [Reaction30](#) and as a product in [Reaction28](#)).

$$\frac{d}{dt}\text{MAPKppMAPKPH} = v_{28} - v_{29} - v_{30} \quad (68)$$

## 6.9 Species MEK

**Name** MEK

**Initial amount** 0.2  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction7](#) and as a product in [Reaction8](#), [Reaction12](#)).

$$\frac{d}{dt}\text{MEK} = v_8 + v_{12} - v_7 \quad (69)$$

## 6.10 Species MEKp

**Name** MEK-P

**Initial amount** 0  $\mu\text{mol}$

This species takes part in six reactions (as a reactant in [Reaction10](#), [Reaction13](#) and as a product in [Reaction9](#), [Reaction11](#), [Reaction14](#), [Reaction18](#)).

$$\frac{d}{dt}\text{MEKp} = v_9 + v_{11} + v_{14} + v_{18} - v_{10} - v_{13} \quad (70)$$

### 6.11 Species MEKPH

**Name** MEK phosphatase

**Initial amount** 0.2  $\mu\text{mol}$

This species takes part in six reactions (as a reactant in [Reaction10](#), [Reaction16](#) and as a product in [Reaction11](#), [Reaction12](#), [Reaction17](#), [Reaction18](#)).

$$\frac{d}{dt}\text{MEKPH} = v_{11} + v_{12} + v_{17} + v_{18} - v_{10} - v_{16} \quad (71)$$

### 6.12 Species MEKpMEKPH

**Name** MEK-P\_MEKPase

**Initial amount** 0  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction11](#), [Reaction12](#) and as a product in [Reaction10](#)).

$$\frac{d}{dt}\text{MEKpMEKPH} = v_{10} - v_{11} - v_{12} \quad (72)$$

### 6.13 Species MEKpp

**Name** MEK-PP

**Initial amount** 0  $\mu\text{mol}$

This species takes part in nine reactions (as a reactant in [Reaction16](#), [Reaction19](#), [Reaction25](#) and as a product in [Reaction15](#), [Reaction17](#), [Reaction20](#), [Reaction21](#), [Reaction26](#), [Reaction27](#)).

$$\frac{d}{dt}\text{MEKpp} = v_{15} + v_{17} + v_{20} + v_{21} + v_{26} + v_{27} - v_{16} - v_{19} - v_{25} \quad (73)$$

### 6.14 Species MEKppMEKPH

**Name** MEK-PP\_MEKPase

**Initial amount** 0  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction17](#), [Reaction18](#) and as a product in [Reaction16](#)).

$$\frac{d}{dt}\text{MEKppMEKPH} = v_{16} - v_{17} - v_{18} \quad (74)$$

### 6.15 Species MEKpRAFp

**Name** MEK-P\_RAF-P

**Initial amount** 0  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction14](#), [Reaction15](#) and as a product in [Reaction13](#)).

$$\frac{d}{dt}\text{MEKpRAFp} = v_{13} - v_{14} - v_{15} \quad (75)$$

### 6.16 Species MEKRAFp

**Name** MEK\_RAF-P

**Initial amount** 0  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction8](#), [Reaction9](#) and as a product in [Reaction7](#)).

$$\frac{d}{dt}\text{MEKRAFp} = v_7 - v_8 - v_9 \quad (76)$$

### 6.17 Species RAF

**Name** RAF

**Initial amount** 0.3  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction1](#) and as a product in [Reaction2](#), [Reaction6](#)).

$$\frac{d}{dt}\text{RAF} = v_2 + v_6 - v_1 \quad (77)$$

### 6.18 Species RAFK

**Name** RAFK

**Initial amount** 0.2  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction1](#) and as a product in [Reaction2](#), [Reaction3](#)).

$$\frac{d}{dt}\text{RAFK} = v_2 + v_3 - v_1 \quad (78)$$



## 6.19 Species RAFp

**Name** RAF-P

**Initial amount** 0  $\mu\text{mol}$

This species takes part in nine reactions (as a reactant in [Reaction4](#), [Reaction7](#), [Reaction13](#) and as a product in [Reaction3](#), [Reaction5](#), [Reaction8](#), [Reaction9](#), [Reaction14](#), [Reaction15](#)).

$$\frac{d}{dt}\text{RAFp} = v_3 + v_5 + v_8 + v_9 + v_{14} + v_{15} - v_4 - v_7 - v_{13} \quad (79)$$

## 6.20 Species RAFPH

**Name** RAF phosphatase

**Initial amount** 0.3  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction4](#) and as a product in [Reaction5](#), [Reaction6](#)).

$$\frac{d}{dt}\text{RAFPH} = v_5 + v_6 - v_4 \quad (80)$$

## 6.21 Species RAFpRAFPH

**Name** RAF-P\_RAFPase

**Initial amount** 0  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction5](#), [Reaction6](#) and as a product in [Reaction4](#)).

$$\frac{d}{dt}\text{RAFpRAFPH} = v_4 - v_5 - v_6 \quad (81)$$

## 6.22 Species RAFRAFK

**Name** RAF\_RAFK

**Initial amount** 0  $\mu\text{mol}$

This species takes part in three reactions (as a reactant in [Reaction2](#), [Reaction3](#) and as a product in [Reaction1](#)).

$$\frac{d}{dt}\text{RAFRAFK} = v_1 - v_2 - v_3 \quad (82)$$

SBML<sup>2</sup>AT<sub>E</sub>X was developed by Andreas Dräger<sup>a</sup>, Hannes Planatscher<sup>a</sup>, Dieudonné M Wouamba<sup>a</sup>, Adrian Schröder<sup>a</sup>, Michael Hucka<sup>b</sup>, Lukas Endler<sup>c</sup>, Martin Golebiewski<sup>d</sup> and Andreas Zell<sup>a</sup>. Please see <http://www.ra.cs.uni-tuebingen.de/software/SBML2LaTeX> for more information.

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