**SBML Model Report**

# Model name: “Wu2006_K+Channel”

May 6, 2016

## 1 General Overview

This is a document in SBML Level 2 Version 1 format. This model was created by Enuo He[1] at June 25th 2007 at 4:36 p. m. and last time modified at February 28th 2014 at 4:06 p. m. Table 1 provides 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 | 2 |
| events | 1 | constraints | 0 |
| reactions | 2 | function definitions | 0 |
| global parameters | 57 | unit definitions | 3 |
| rules | 28 | initial assignments | 0 |

### Model Notes

The model is described in the paper by Wu and Chang (2006). Diethyl pyrocarbonate, a histidine-modifying agent, directly stimulates activity of ATP-sensitive potassium channels in pituitary GH3 cells. Biochem Pharmacol. 71(5): 615-23.

The unit of time is ms, and the simulation time is 80 s, that is 8e4 ms. Therfore, you probably need to increase the maximum steps for your simulator.

The figure 7 has been reproduced by MathSBML. Application of DEPC as indicated at horizontal bar was mimicked by an increase of maximal conductance of Katp-channels from 500 to

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530 ps at t=30 s.



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## 2 Unit Definitions

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

### 2.1 Unit `time`

**Name** millisecond

**Definition** ms

### 2.2 Unit `mV`

**Name** millivolt

**Definition** mV

### 2.3 Unit `substance`

**Name** micromole

**Definition** µmol

### 2.4 Unit `volume`

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

**Definition** l

### 2.5 Unit `area`

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

**Definition** $m^2$

### 2.6 Unit `length`

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

**Definition** m

## 3 Compartment

This model contains one compartment.

Table 2: Properties of all compartments.

| Id | Name | SBO | Spatial Dimensions | Size | Unit | Constant | Outside |
|---|---|---|---|---|---|---|---|
| `cell` | GH3 cell | | 3 | 1 | litre | ☑ | |

### 3.1 Compartment `cell`

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

**Name** GH3 cell

## 4 Species

This model contains two species. 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 |
|---|---|---|---|---|---|
| `c` | cytosolic free ca concentration | `cell` | $\mu\mathrm{mol} \cdot \mathrm{l}^{-1}$ | $\boxminus$ | $\boxminus$ |
| `cer` | ER ca concentration | `cell` | $\mu\mathrm{mol} \cdot \mathrm{l}^{-1}$ | $\boxminus$ | $\boxminus$ |

## 5 Parameters

This model contains 57 global parameters.

Table 4: Properties of each parameter.

| Id | Name | SBO | Value | Unit | Constant |
|---|---|---|---|---|---|
| gca | ca current conductance | | 1000.000 | | ☑ |
| gkca | ca activated k conductance | | 900.000 | | ☑ |
| gk | k current conductance | | 1400.000 | | ☑ |
| gir | erg k current conductance | | 5.000 | | ☑ |
| vca | ca reversal potential | | 50.000 | | ☑ |
| vk | k reversal potential | | $-75.000$ | | ☑ |
| vir | | | $-75.000$ | | ☑ |
| cm | membrane capacitance | | 5300.000 | | ☑ |
| taun | | | 16.000 | | ☑ |
| alpha | | | $4.5 \cdot 10^{-6}$ | | ☑ |
| fcyt | | | 0.010 | | ☑ |
| kpmca | | | 0.200 | | ☑ |
| kd | | | 0.300 | | ☑ |
| vn | | | $-16.000$ | | ☑ |
| vm | | | $-20.000$ | | ☑ |
| sn | | | 5.000 | | ☑ |
| sm | | | 12.000 | | ☑ |
| kserca | | | 0.400 | | ☑ |
| dact | | | 0.350 | | ☑ |
| dinact | | | 0.400 | | ☑ |
| fer | | | 0.010 | | ☑ |
| pleak | | | $5 \cdot 10^{-4}$ | | ☑ |
| dip3 | | | 0.500 | | ☑ |
| vcytver | | | 5.000 | | ☑ |
| ip3 | | | 0.000 | | ☑ |
| sa | | | 0.100 | | ☑ |
| r | | | 0.140 | | ☑ |
| taua | | | 300000.000 | | ☑ |
| gkatp | | | 500.000 | | ☐ |
| alphaIRn | | | 0.000 | | ☐ |
| betaIRn | | | 0.000 | | ☐ |

| Id | Name | SBO | Value | Unit | Constant |
|---|---|---|---|---|---|
| nIRinf | | | 0.000 | | ☐ |
| tauIRn | | | 0.000 | | ☐ |
| alphaIRr | | | 0.000 | | ☐ |
| betaIRr | | | 0.000 | | ☐ |
| rIRinf | | | 0.000 | | ☐ |
| tauIRr | | | 0.000 | | ☐ |
| ica | calcium current | | 0.000 | | ☐ |
| ik | delayed rectifier k current | | 0.000 | | ☐ |
| ikca | ca dependent k current | | 0.000 | | ☐ |
| ikatp | nucleotide sensitive k current | | 0.000 | | ☐ |
| iir | erg like k current | | 0.000 | | ☐ |
| minf | | | 0.000 | | ☐ |
| ninf | | | 0.000 | | ☐ |
| ainf | | | 0.000 | | ☐ |
| w | | | 0.000 | | ☐ |
| jmem | | | 0.000 | | ☐ |
| jserca | | | 0.000 | | ☐ |
| jleak | | | 0.000 | | ☐ |
| jip3 | | | 0.000 | | ☐ |
| oinf | | | 0.000 | | ☐ |
| jer | | | 0.000 | | ☐ |
| V | | | −60.000 | | ☐ |
| n | | | 0.010 | | ☐ |
| a | | | 0.460 | | ☐ |
| nIR | | | 0.008 | | ☐ |
| rIR | | | 0.282 | | ☐ |

# 6 Rules

This is an overview of 28 rules.

## 6.1 Rule alphaIRn

Rule alphaIRn is an assignment rule for parameter alphaIRn:

$$\mathrm{alphaIRn} = \frac{0.09}{1 + \exp\left(0.11 \cdot (\mathrm{V} + 100)\right)} \tag{1}$$

## 6.2 Rule betaIRn

Rule betaIRn is an assignment rule for parameter betaIRn:

$$\text{betaIRn} = 3.5 \cdot 10^{-4} \cdot \exp\left(0.07 \cdot (\text{V} + 25)\right) \tag{2}$$

## 6.3 Rule nIRinf

Rule nIRinf is an assignment rule for parameter nIRinf:

$$\text{nIRinf} = \frac{1}{1 + \frac{\text{betaIRn}}{\text{alphaIRn}}} \tag{3}$$

## 6.4 Rule tauIRn

Rule tauIRn is an assignment rule for parameter tauIRn:

$$\text{tauIRn} = \frac{1}{\text{alphaIRn} + \text{betaIRn}} \tag{4}$$

## 6.5 Rule alphaIRr

Rule alphaIRr is an assignment rule for parameter alphaIRr:

$$\text{alphaIRr} = \frac{30}{1 + \exp\left(0.04 \cdot (\text{V} + 230)\right)} \tag{5}$$

## 6.6 Rule betaIRr

Rule betaIRr is an assignment rule for parameter betaIRr:

$$\text{betaIRr} = \frac{0.15}{1 + \exp\left(-0.05 \cdot (\text{V} + 120)\right)} \tag{6}$$

## 6.7 Rule rIRinf

Rule rIRinf is an assignment rule for parameter rIRinf:

$$\text{rIRinf} = \frac{1}{1 + \frac{\text{betaIRr}}{\text{alphaIRr}}} \tag{7}$$

## 6.8 Rule tauIRr

Rule tauIRr is an assignment rule for parameter tauIRr:

$$\text{tauIRr} = \frac{1}{\text{alphaIRr} + \text{betaIRr}} \tag{8}$$

### 6.9 Rule minf

Rule `minf` is an assignment rule for parameter `minf`:

$$\mathrm{minf} = \frac{1}{1 + \exp\left(\frac{\mathrm{vm} - \mathrm{V}}{\mathrm{sm}}\right)} \tag{9}$$

**Notes** activation function

### 6.10 Rule ik

Rule `ik` is an assignment rule for parameter `ik`:

$$\mathrm{ik} = \mathrm{gk} \cdot \mathrm{n} \cdot (\mathrm{V} - \mathrm{vk}) \tag{10}$$

**Notes** delayed rectifier K+ current

### 6.11 Rule w

Rule `w` is an assignment rule for parameter `w`:

$$\mathrm{w} = \frac{[\mathrm{c}]^5}{[\mathrm{c}]^5 + \mathrm{kd}^5} \tag{11}$$

**Notes** Fraction of K(ca) channels activated by cytosolic Ca2+

### 6.12 Rule ikatp

Rule `ikatp` is an assignment rule for parameter `ikatp`:

$$\mathrm{ikatp} = \mathrm{gkatp} \cdot \mathrm{a} \cdot (\mathrm{V} - \mathrm{vk}) \tag{12}$$

**Notes** nucleotide-sensitive K+ current

### 6.13 Rule ica

Rule `ica` is an assignment rule for parameter `ica`:

$$\mathrm{ica} = \mathrm{gca} \cdot \mathrm{minf} \cdot (\mathrm{V} - \mathrm{vca}) \tag{13}$$

**Notes** Ca ionic currents

### 6.14 Rule ninf

Rule `ninf` is an assignment rule for parameter `ninf`:

$$\mathrm{ninf} = \frac{1}{1 + \exp\left(\frac{\mathrm{vn} - \mathrm{V}}{\mathrm{sn}}\right)} \tag{14}$$

**Notes** activation function

### 6.15 Rule `ainf`

Rule `ainf` is an assignment rule for parameter `ainf`:

$$\text{ainf} = \frac{1}{1+\exp\left(\frac{\text{r}-[\text{c}]}{\text{sa}}\right)} \tag{15}$$

**Notes** activation function

### 6.16 Rule `ikca`

Rule `ikca` is an assignment rule for parameter `ikca`:

$$\text{ikca} = \text{gkca} \cdot \text{w} \cdot (\text{V} - \text{vk}) \tag{16}$$

**Notes** Ca2+ dependent K+ current

### 6.17 Rule `jmem`

Rule `jmem` is an assignment rule for parameter `jmem`:

$$\text{jmem} = (\text{alpha} \cdot \text{ica} + \text{kpmca} \cdot [\text{c}]) \tag{17}$$

**Derived unit** $\mu\text{mol} \cdot \text{l}^{-1}$

**Notes** Flux of Ca2+ through the membrane

### 6.18 Rule `jserca`

Rule `jserca` is an assignment rule for parameter `jserca`:

$$\text{jserca} = \text{kserca} \cdot [\text{c}] \tag{18}$$

**Notes** Ca2+ flux into the ER via SERCA

### 6.19 Rule `jleak`

Rule `jleak` is an assignment rule for parameter `jleak`:

$$\text{jleak} = \text{pleak} \cdot ([\text{cer}] - [\text{c}]) \tag{19}$$

**Notes** Ca2+ leak is proportional to gradient between Ca2+ and ER

### 6.20 Rule `oinf`

Rule `oinf` is an assignment rule for parameter `oinf`:

$$\text{oinf} = \frac{[\text{c}]}{\text{dact} + [\text{c}]} \cdot \frac{\text{ip3}}{\text{dip3} + \text{ip3}} \cdot \frac{\text{dinact}}{\text{dinact} + [\text{c}]} \tag{20}$$

**Notes** fraction of open channels

### 6.21 Rule `jip3`

Rule `jip3` is an assignment rule for parameter `jip3`:

$$\text{jip3} = \text{oinf} \cdot ([\text{cer}] - [\text{c}]) \tag{21}$$

**Notes** Ca2+ efflux through the IP3R

### 6.22 Rule `jer`

Rule `jer` is an assignment rule for parameter `jer`:

$$\text{jer} = \text{jleak} + \text{jip3} - \text{jserca} \tag{22}$$

**Notes** net Ca2+ efflux from the ER

### 6.23 Rule `nIR`

Rule `nIR` is a rate rule for parameter `nIR`:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{nIR} = \frac{\text{nIRinf} - \text{nIR}}{\text{tauIRn}} \tag{23}$$

### 6.24 Rule `rIR`

Rule `rIR` is a rate rule for parameter `rIR`:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{rIR} = \frac{\text{rIRinf} - \text{rIR}}{\text{tauIRr}} \tag{24}$$

### 6.25 Rule `iir`

Rule `iir` is an assignment rule for parameter `iir`:

$$\text{iir} = \text{gir} \cdot \text{nIR} \cdot \text{rIR} \cdot (\text{V} - \text{vir}) \tag{25}$$

### 6.26 Rule `n`

Rule `n` is a rate rule for parameter `n`:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{n} = \frac{\text{ninf} - \text{n}}{\text{taun}} \tag{26}$$

### 6.27 Rule `a`

Rule `a` is a rate rule for parameter `a`:

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{a} = \frac{\text{ainf} - \text{a}}{\text{taua}} \tag{27}$$

### 6.28 Rule `V`

Rule `V` is a rate rule for parameter `V`:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{V} = \frac{(\mathrm{ica} + \mathrm{ik} + \mathrm{ikca} + \mathrm{ikatp} + \mathrm{iir})}{\mathrm{cm}} \tag{28}$$

## 7 Event

This is an overview of one event. Each event is initiated whenever its trigger condition switches from `false` to `true`. A delay function postpones the effects of an event to a later time point. At the time of execution, an event can assign values to species, parameters or compartments if these are not set to constant.

### 7.1 Event `event_0000001`

**Notes** Increase of maximal conductance of K_ATP channels from 500 to 530 at time=30000 ms

**Trigger condition**

$$\mathrm{time} > 30000.0 \tag{29}$$

**Assignment**

$$\mathrm{gkatp} = 530 \tag{30}$$

# 8 Reactions

This model contains two 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 | `reaction-_0000005` | cytosolic free Ca2+ concentration | $\emptyset \longrightarrow \mathrm{c}$ | |
| 2 | `reaction-_0000006` | ER Ca2+ concentration | $\emptyset \longrightarrow \mathrm{cer}$ | |

## 8.1 Reaction reaction_0000005

This is an irreversible reaction of no reactant forming one product.

**Name** cytosolic free Ca2+ concentration

### Reaction equation

$$\emptyset \longrightarrow \mathrm{c} \tag{31}$$

### Product

Table 6: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| c | cytosolic free ca concentration | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_1 = \mathrm{vol}\left(\mathrm{cell}\right) \cdot \mathrm{fcyt} \cdot \left(\mathrm{jmem} + \mathrm{jer}\right) \tag{32}$$

## 8.2 Reaction reaction_0000006

This is an irreversible reaction of no reactant forming one product.

**Name** ER Ca2+ concentration

### Reaction equation

$$\emptyset \longrightarrow \mathrm{cer} \tag{33}$$

### Product

Table 7: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| cer | ER ca concentration | |

### Kinetic Law

**Derived unit** contains undeclared units

$$v_2 = \mathrm{fer} \cdot \mathrm{vcytver} \cdot \mathrm{jer} \cdot \mathrm{vol}\left(\mathrm{cell}\right) \tag{34}$$

# 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 `c`

**Name** cytosolic free ca concentration

**Initial concentration** $0.1\ \mu\text{mol}\cdot\text{l}^{-1}$

This species takes part in one reaction (as a product in `reaction_0000005`).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{c} = v_1 \tag{35}$$

## 9.2 Species `cer`

**Name** ER ca concentration

**Initial concentration** $100\ \mu\text{mol}\cdot\text{l}^{-1}$

This species takes part in one reaction (as a product in `reaction_0000006`).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{cer} = v_2 \tag{36}$$

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

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