Zero Order

```
> restart;with( DEtools ):with( plots ):with (linalg):
> ode_1:=diff(ca(t),t)=-k_1;ode_2:=diff(cb(t),t)=(k_1);
```

$$ode\_1 := \frac{d}{dt}\, ca(t) = -k\_1$$

$$ode\_2 := \frac{d}{dt}\, cb(t) = k\_1 \qquad (1.1)$$

```
> dsolve({ode_1,ca(0)=ca0},ca(t));
```

$$ca(t) = -k\_1\, t + ca0$$

```
> dsolve({ode_2,cb(0)=cb0},cb(t));
```

$$cb(t) = k\_1\, t + cb0$$

```
> sol:= dsolve({ode_1,ca(0)=ca0,ode_2,cb(0)=cb0},{ca(t),cb(t)})
  ;
```

$$sol := \{ca(t) = -k\_1\, t + ca0,\ cb(t) = k\_1\, t + cb0\}$$

```
> k_1:=1:nsol := dsolve({ode_1,ca(0)=1,ode_2,cb(0)=0}, type=
  numeric, output=listprocedure);#assign(nsol);f:=eval(ca(t),
  sol);f(t=1);
```

nsol := [*t* = **proc**(*t*) ... **end proc**, *ca*(*t*) = **proc**(*t*) ... **end proc**, *cb*(*t*) = **proc**(*t*)

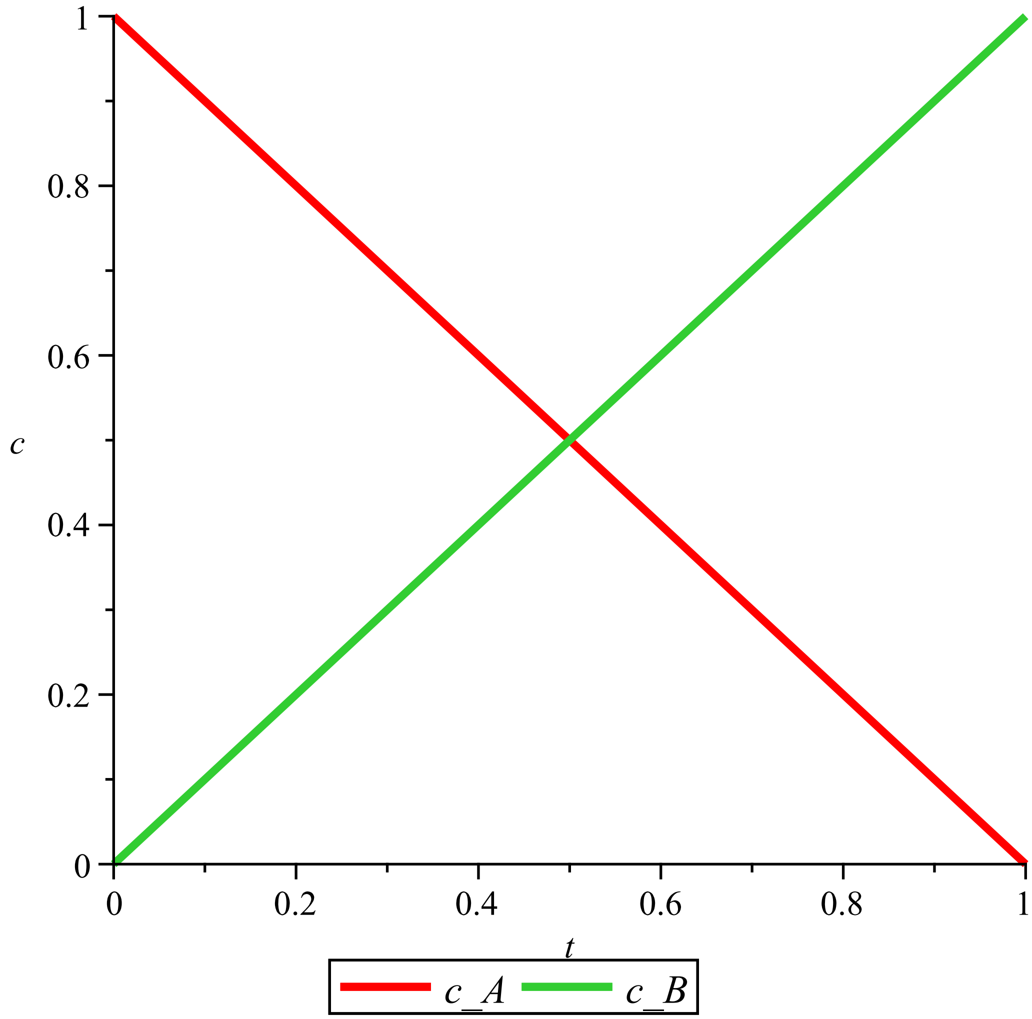
...

end proc]

```
> nsol(1);
```

$$[t(1) = 1.,\ ca(t)(1) = 6.93889390390723\ 10^{-18},\ cb(t)(1) = 1.] \qquad (1.2)$$

```
> odeplot(nsol,[[t,ca(t)],[t,cb(t)]],0..1,labels=[t,c],legend=
  [c_A,c_B],thickness=3);
```




```
> 
```

Prvniho radu A ->B

```
> restart;with( DEtools ):with( plots ):with (linalg):
> ode_1:=diff(ca(t),t)=-k_1*ca(t);
```

$$ode\_1 := \frac{d}{dt}\, ca(t) = -k\_1\, ca(t)$$

```
> ode_2:=diff(cb(t),t)=(k_1)*ca(t);
```

$$ode\_2 := \frac{d}{dt}\, cb(t) = k\_1\, ca(t)$$

```
> dsolve({ode_1,ca(0)=ca0},ca(t));
```

$$ca(t) = ca0\, e^{-k\_1\, t}$$

```
> dsolve({ode_2,cb(0)=cb0},cb(t));
```

$$cb(t) = \int_0^t k\_1\, ca(\_z1)\, \mathrm{d}\_z1 + cb0$$

```
> sol:= dsolve({ode_1,ca(0)=ca0,ode_2,cb(0)=cb0},{ca(t),cb(t)})
  ;
```

$$sol := \{ca(t) = ca0\, \mathrm{e}^{-k\_1 t}, cb(t) = -ca0\, \mathrm{e}^{-k\_1 t} + ca0 + cb0\}$$

```
> k_1:=1:nsol := dsolve({ode_1,ca(0)=1,ode_2,cb(0)=0}, type=
  numeric, output=listprocedure);#assign(nsol);f:=eval(ca(t),
  sol);f(t=1);
```

nsol := [*t* = **proc**(*t*) ... **end proc**, *ca*(*t*) = **proc**(*t*) ... **end proc**, *cb*(*t*) = **proc**(*t*)

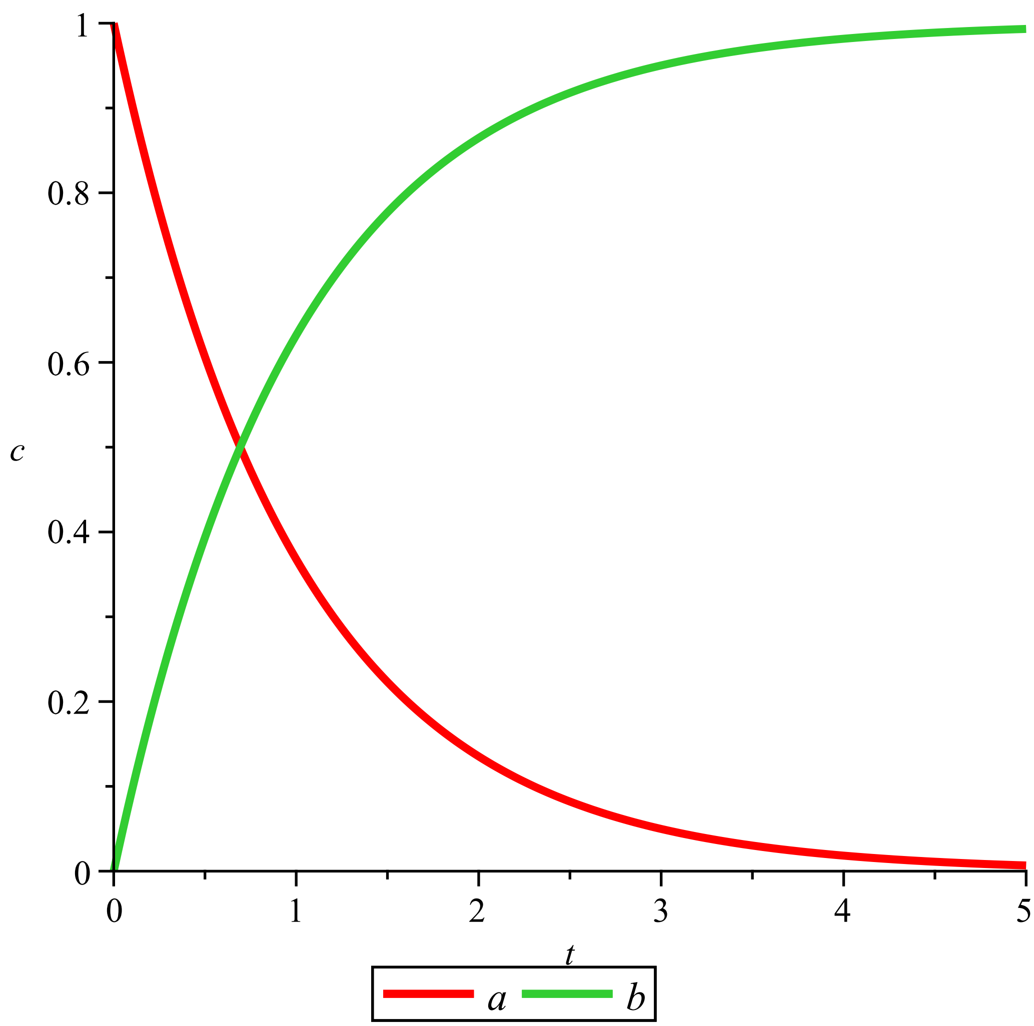
...

end proc]

```
> nsol(1);
```

$$[t(1) = 1., ca(t)(1) = 0.367879361988637, cb(t)(1) = 0.632120638011363] \qquad \textbf{(2.1)}$$

```
> odeplot(nsol,[[t,ca(t)],[t,cb(t)]],0..5,labels=[t,c],legend=
  [a,b],thickness=3);
```



Reakce druheho radu 2A->B

```
> restart;with( DEtools ):with( plots ):with (linalg ):
> ode_1:=diff(ca(t),t)=-k_1*(ca(t))^2;
```

$$ode\_1 := \frac{d}{dt}\, ca(t) = -k\_1\, ca(t)^2$$

```
> ode_2:=diff(cb(t),t)=(k_1)*(ca(t))^2;
```

$$ode\_2 := \frac{d}{dt}\, cb(t) = k\_1\, ca(t)^2$$

```
> dsolve({ode_1,ca(0)=ca0},ca(t));
```

$$ca(t) = \frac{ca0}{1 + k\_1\, t\, ca0}$$

```
> dsolve({ode_2,cb(0)=ca0},cb(t));
```

$$cb(t) = \int_0^t k\_1\, ca(\_z1)^2\, d\_z1 + ca0$$

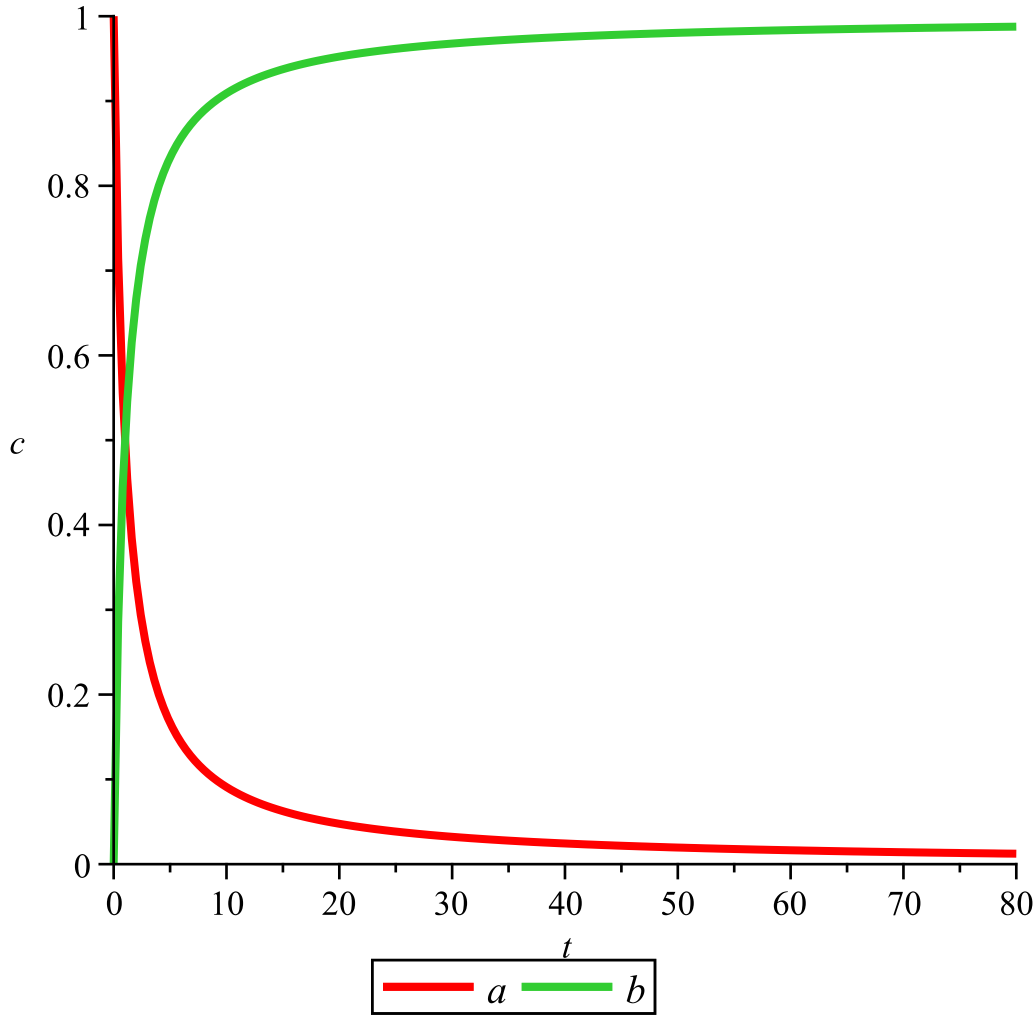
```
> dsolve({ode_1,ca(0)=ca0,ode_2,cb(0)=cb0},{ca(t),cb(t)});
```

$$\left\{ ca(t) = \frac{1}{k\_1\, t + \frac{1}{ca0}},\ cb(t) = -\frac{1}{k\_1\, t + \frac{1}{ca0}} + ca0 + cb0 \right\}$$

```
> k_1:=1:nsol := dsolve({ode_1,ca(0)=1,ode_2,cb(0)=0}, type=
  numeric);
```

$nsol :=$ **proc**(x_rkf45) ... **end proc**

```
> odeplot(nsol,[[t,ca(t)],[t,cb(t)]],0..80,labels=[t,c],legend=
  [a,b],thickness=3);
```



Reakce druheho radu A+B->C

```
> restart;with( DEtools ):with( plots ):with (linalg ):
> ode_1:=diff(ca(t),t)=-k_1*(ca(t))*(cb(t));
```

$$ode\_1 := \frac{d}{dt} ca(t) = -k\_1\, ca(t)\, cb(t)$$

```
> ode_2:=diff(cb(t),t)=-k_1*(ca(t))*(cb(t));
```

$$ode\_2 := \frac{d}{dt} cb(t) = -k\_1\, ca(t)\, cb(t)$$

```
> ode_3:=diff(cc(t),t)=k_1*(ca(t))*(cb(t));
```

$$ode\_3 := \frac{d}{dt} cc(t) = k\_1\, ca(t)\, cb(t) \tag{4.1}$$

```
> dsolve({ode_1,ca(0)=ca0},ca(t));
```

$$ca(t) = ca0\, e^{\int_0^t (-k\_1\, cb(\_z1))\, d\_z1}$$

```
> dsolve({ode_2,cb(0)=ca0},cb(t));
```

$$cb(t) = ca0\, e^{\int_0^t (-k\_1\, ca(\_z1))\, d\_z1}$$

```
> dsolve({ode_1,ca(0)=ca0,ode_2,cb(0)=cb0,ode_3,cc(0)=cc0},{ca(t),cb(t),cc(t)});
```

$$\Bigg\{ ca(t) = \Bigg(\left(e^{I\pi\_Z1\sim}\right)^2 e^{t(-cb0\, k\_1 + k\_1\, ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\, k\_1}\right) + 2 I \pi\_Z2\sim\right)(-cb0\, k\_1 + k\_1\, ca0)}{k\_1(-cb0 + ca0)}} (-cb0\, k\_1$$

$$+ k\_1\, ca0) \Bigg) \Bigg/ \Bigg(-1$$

$$+ k\_1\, e^{t(-cb0\, k\_1 + k\_1\, ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\, k\_1}\right) + 2 I \pi\_Z2\sim\right)(-cb0\, k\_1 + k\_1\, ca0)}{k\_1(-cb0 + ca0)}} \Bigg), cb(t) =$$

$$-\Bigg(\Bigg(\Bigg(\left(e^{I\pi\_Z1\sim}\right)^2 (-cb0\, k\_1$$

$$+ k\_1\, ca0)^2\, e^{t(-cb0\, k\_1 + k\_1\, ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\, k\_1}\right) + 2 I \pi\_Z2\sim\right)(-cb0\, k\_1 + k\_1\, ca0)}{k\_1(-cb0 + ca0)}} \Bigg) \Bigg/ \Bigg(-1$$

$$+ k\_1\, e^{t(-cb0\,k\_1 + k\_1\,ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\,k\_1}\right) + 2\,I\,\pi\,\_Z2\sim\right)(-cb0\,k\_1 + k\_1\,ca0)}{k\_1(-cb0 + ca0)}}\Bigg)$$

$$a0)\; e^{\frac{\left(\ln\left(\frac{ca0}{cb0\,k\_1}\right) + 2\,I\,\pi\,\_Z2\sim\right)(-cb0\,k\_1 + k\_1\,ca0)}{k\_1(-cb0 + ca0)}}\Bigg)^2\Bigg)\Bigg(-1$$

$$- \; + k\_1\, e^{t(-cb0\,k\_1 + k\_1\,ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\,k\_1}\right) + 2\,I\,\pi\,\_Z2\sim\right)(-cb0\,k\_1 + k\_1\,ca0)}{k\_1(-cb0 + ca0)}}\Bigg)\Bigg) \Big/$$

$$\Bigg(k\_1\,\left(e^{I\,\pi\,\_Z1\sim}\right)^2 e^{t(-cb0\,k\_1 + k\_1\,ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\,k\_1}\right) + 2\,I\,\pi\,\_Z2\sim\right)(-cb0\,k\_1 + k\_1\,ca0)}{k\_1(-cb0 + ca0)}}\,(-cb0\,k\_1$$

$$+ k\_1\,ca0)\Bigg),\; cc(t) =$$

$$-\Bigg(\left(e^{I\,\pi\,\_Z1\sim}\right)^2 e^{t(-cb0\,k\_1 + k\_1\,ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\,k\_1}\right) + 2\,I\,\pi\,\_Z2\sim\right)(-cb0\,k\_1 + k\_1\,ca0)}{k\_1(-cb0 + ca0)}}\,(-cb0\,k\_1$$

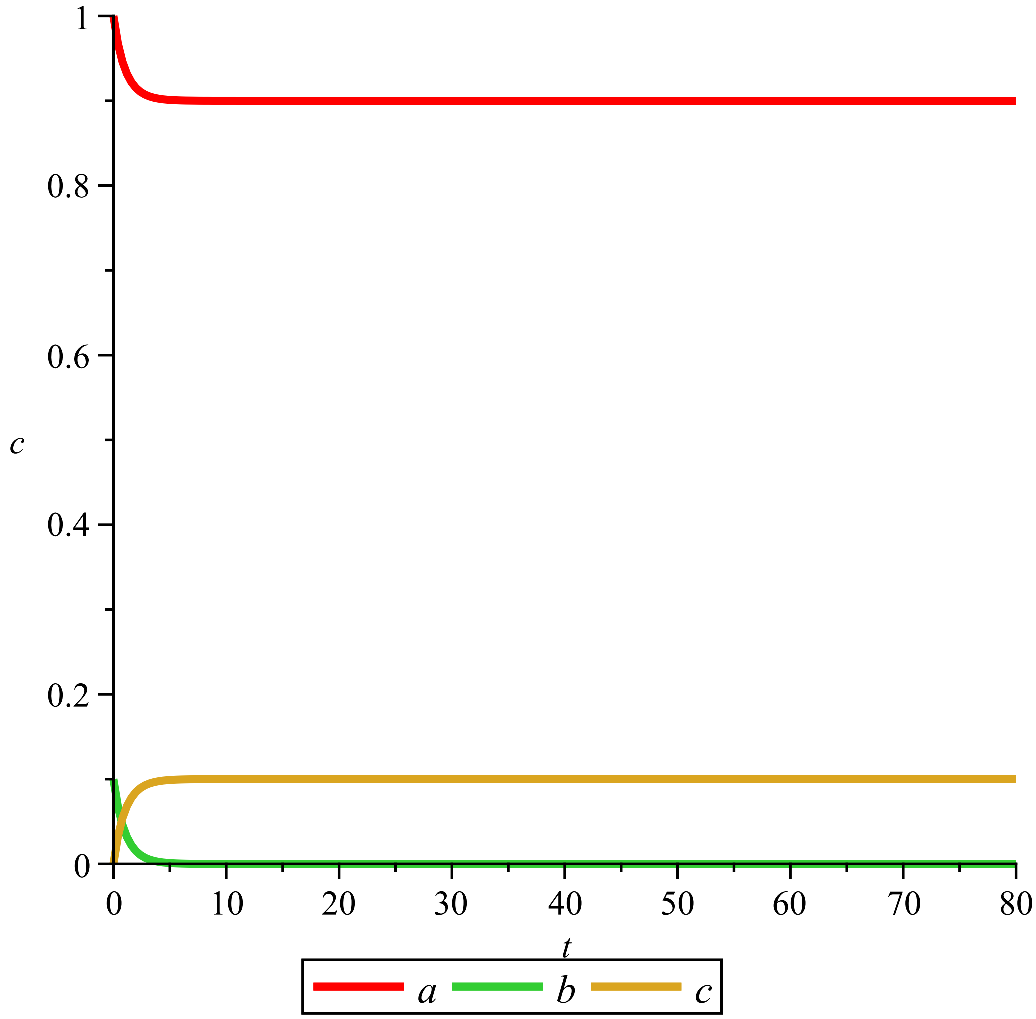
$$+ k\_1\,ca0)\Bigg) \Big/ \Bigg(-1$$

$$+ k\_1\, e^{t(-cb0\,k\_1 + k\_1\,ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\,k\_1}\right) + 2\,I\,\pi\,\_Z2\sim\right)(-cb0\,k\_1 + k\_1\,ca0)}{k\_1(-cb0 + ca0)}}\Bigg) + ca0 + cc0\Big\}$$

```
> k_1:=1:nsol := dsolve({ode_1,ca(0)=1,ode_2,cb(0)=.1,ode_3,cc
(0)=0}, type=numeric);
```

$$nsol := \textbf{proc}(x\_rkf45)\ \ldots\ \textbf{end proc}$$

```
> odeplot(nsol,[[t,ca(t)],[t,cb(t)],[t,cc(t)]],0..80,labels=[t,
c],legend=[a,b,c],thickness=3);
```



Srovnání prvního a druhého ádu

```
> restart;with( DEtools ):with( plots ):with (linalg):
> ode_1:=diff(ca(t),t)=-k_1*ca(t);
```

$$ode\_1 := \frac{d}{dt}\,ca(t) = -k\_1\,ca(t)$$

```
> ode_2:=diff(cb(t),t)=-(k_1)*(cb(t))^2;
```

$$ode\_2 := \frac{d}{dt}\,cb(t) = -k\_1\,cb(t)^2$$

```
> dsolve({ode_1,ca(0)=ca0},ca(t));
```

$$ca(t) = ca0\,e^{-k\_1\,t}$$

```
> dsolve({ode_2,cb(0)=cb0},cb(t));
```

$$cb(t) = \frac{cb0}{1 + k\_1\,t\,cb0}$$

```
> sol:= dsolve({ode_1,ca(0)=ca0,ode_2,cb(0)=cb0},{ca(t),cb(t)})
;
```

$$sol := \left\{ ca(t) = ca0\, e^{-k\_1\, t},\ cb(t) = \frac{1}{k\_1\, t + \frac{1}{cb0}} \right\}$$

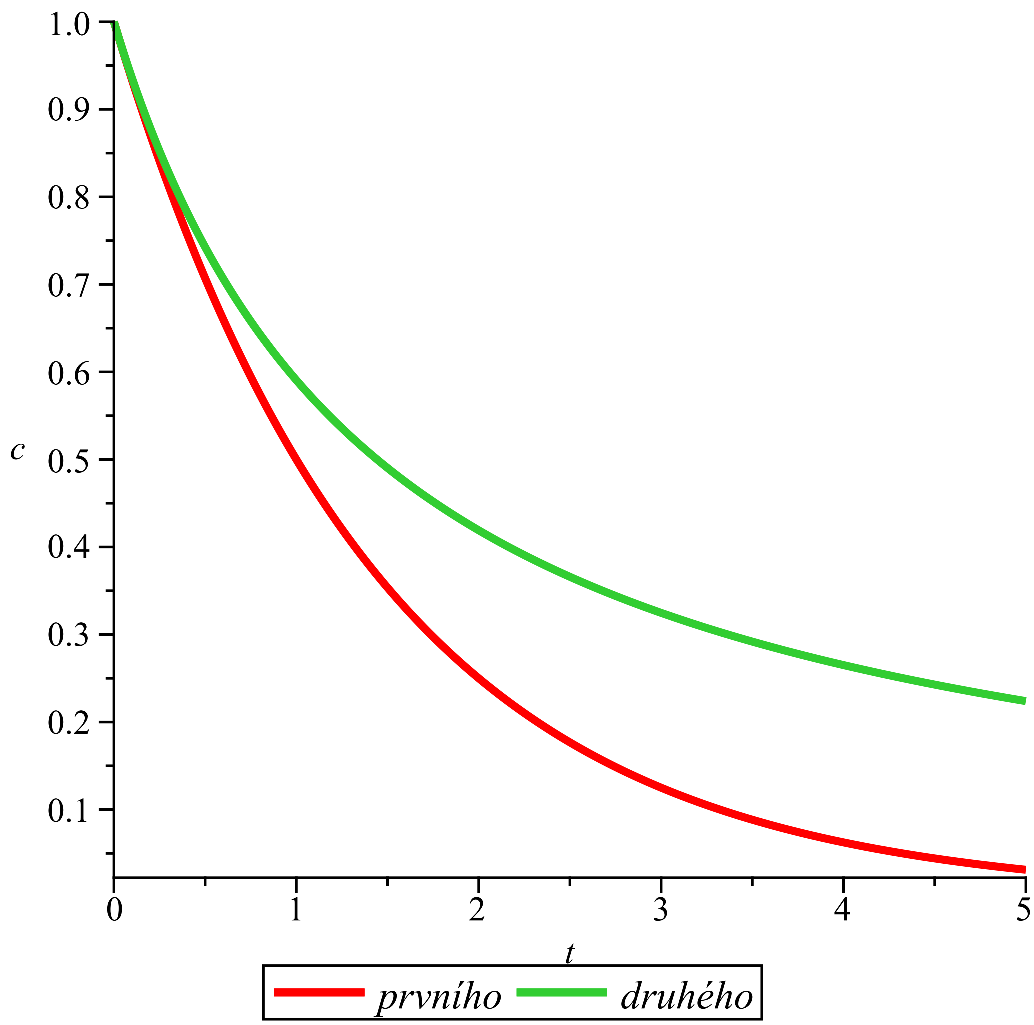
```
> k_1:=log(2):nsol := dsolve({ode_1,ca(0)=1,ode_2,cb(0)=1},
  type=numeric, output=listprocedure);#assign(nsol);f:=eval(ca
  (t), sol);f(t=1);
```

nsol := [*t* = **proc**(*t*) ... **end proc**, *ca*(*t*) = **proc**(*t*) ... **end proc**, *cb*(*t*) = **proc**(*t*)
...
end proc]

```
> %nsol(1);
```

%*nsol*(1) **(5.1)**

```
> odeplot(nsol,[[t,ca(t)],[t,cb(t)]],0..5,labels=[t,c],legend=
  [prvního,druhého],thickness=3);
```



Paralelni reakce A->B,A->C

```
> restart;with( DEtools ):with( plots ):with (linalg ):
> ode_1:=diff(ca(t),t)=-(k_1+k_2)*ca(t);
```

$$ode\_1 := \frac{d}{dt}\, ca(t) = -(k\_1 + k\_2)\, ca(t)$$

```
> ode_2:=diff(cb(t),t)=(k_1)*ca(t);
```

$$ode\_2 := \frac{d}{dt}\, cb(t) = k\_1\, ca(t)$$

```
> ode_3:=diff(cc(t),t)=(k_2)*ca(t);
```

$$ode\_3 := \frac{d}{dt}\, cc(t) = k\_2\, ca(t)$$

```
> dsolve({ode_1,ca(0)=ca0,ode_2,cb(0)=cb0,ode_3,cc(0)=cc0},{ca
  (t),cb(t),cc(t)});
```

$$\left\{ca(t) = ca0\, e^{-(k\_1 + k\_2)\, t},\ cb(t) = -\frac{k\_1\, ca0\, e^{-(k\_1 + k\_2)\, t}}{k\_1 + k\_2} + \frac{k\_1\, ca0 + cb0\, k\_1 + cb0\, k\_2}{k\_1 + k\_2},\ cc(t) = -\frac{k\_2\, ca0\, e^{-(k\_1 + k\_2)\, t}}{k\_1 + k\_2} + \frac{k\_2\, ca0 + cc0\, k\_1 + cc0\, k\_2}{k\_1 + k\_2}\right\}$$

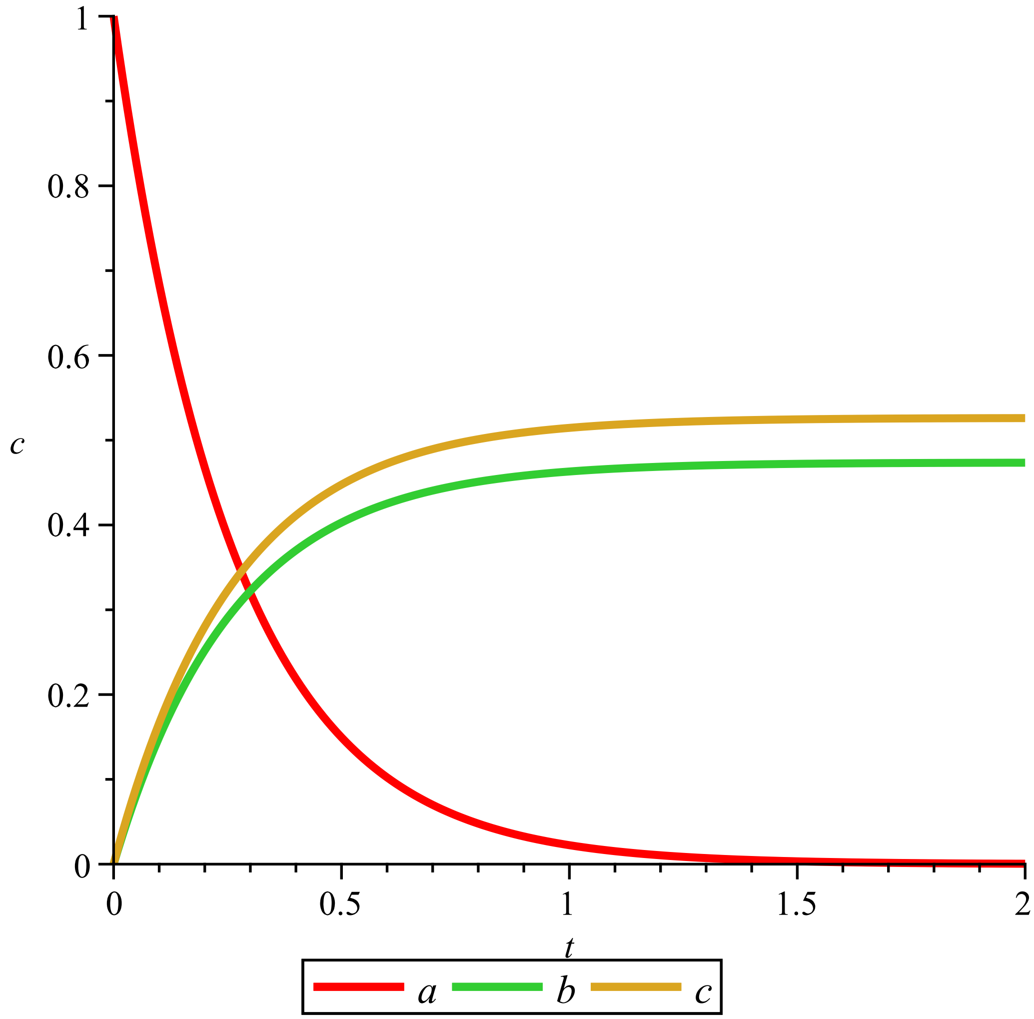
```
> dsolve({ode_2,cb(0)=cb0},cb(t));
```

$$cb(t) = \int_0^t k\_1\, ca(\_z1)\, d\_z1 + cb0$$

```
> k_1:=1.8:k_2:=2:nsol := dsolve({ode_1,ca(0)=1,ode_2,cb(0)=0,
  ode_3,cc(0)=0}, type=numeric);
```

nsol := **proc**(*x_rkf45*) ... **end proc**

```
> odeplot(nsol,[[t,ca(t)],[t,cb(t)],[t,cc(t)]],0..2,labels=[t,
  c],legend=[a,b,c],thickness=3);
```



Nasledne reakce

```
> restart;with( DEtools ):with( plots ):with (linalg):
> ode_1:=diff(ca(t),t)=-k_1*ca(t);
```

$$ode\_1 := \frac{d}{dt}\, ca(t) = -k\_1\, ca(t)$$

```
> ode_2:=diff(cb(t),t)=k_1*ca(t)-k_2*cb(t);
```

$$ode\_2 := \frac{d}{dt}\, cb(t) = k\_1\, ca(t) - k\_2\, cb(t)$$

```
> ode_3:=diff(cc(t),t)=k_2*cb(t);
```

$$ode\_3 := \frac{d}{dt}\, cc(t) = k\_2\, cb(t)$$

```
> dsolve({ode_1,ca(0)=ca0},ca(t));
```

$$ca(t) = ca0\, e^{-k\_1 t}$$

```
> dsolve({ode_2,cb(0)=cb0},cb(t));
```

$$cb(t) = \left(\int_0^t k\_1\, ca(\_z1)\, e^{k\_2\, \_z1}\, d\_z1 + cb0\right) e^{-k\_2 t}$$

```
> dsolve({ode_3,cc(0)=cc0},cc(t));
```

$$cc(t) = \int_0^t k\_2\, cb(\_z1)\, d\_z1 + cc0$$

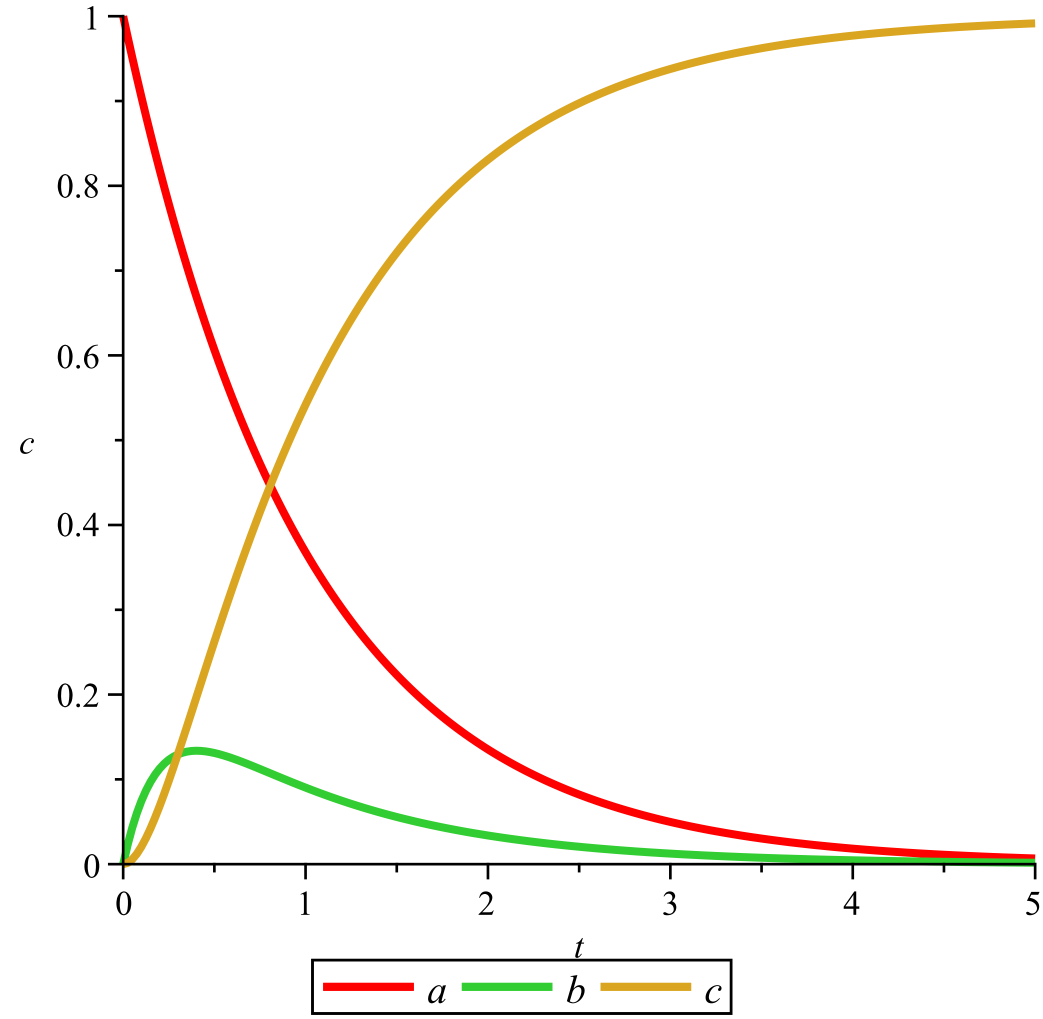
```
> dsolve({ode_1,ca(0)=ca0,ode_2,cb(0)=cb0,ode_3,cc(0)=cc0},{ca(t),cb(t),cc(t)});
```

$$\left\{ ca(t) = ca0\, e^{-k\_1 t},\ cb(t) = -\frac{1}{k\_1 - k\_2}\left(\left(-\frac{(-k\_2\, cb0 + k\_1\, ca0 + cb0\, k\_1)\, k\_1}{k\_1 - k\_2} + \frac{(-k\_2\, cb0 + k\_1\, ca0 + cb0\, k\_1)\, k\_2}{k\_1 - k\_2}\right) e^{-k\_2 t}\right) - \frac{k\_1\, ca0\, e^{-k\_1 t}}{k\_1 - k\_2},\ cc(t) = \frac{1}{k\_1 - k\_2}\left(e^{-k\_1 t}\, ca0\, k\_2 - \frac{e^{-k\_2 t}(-k\_2\, cb0 + k\_1\, ca0 + cb0\, k\_1)\, k\_1}{k\_1 - k\_2} + \frac{e^{-k\_2 t}(-k\_2\, cb0 + k\_1\, ca0 + cb0\, k\_1)\, k\_2}{k\_1 - k\_2} + (cc0 + ca0 + cb0)\, k\_1 - (cc0 + ca0 + cb0)\, k\_2\right)\right\}$$

```
> k_1:=1:k_2:=5:nsol := dsolve({ode_1,ca(0)=1,ode_2,cb(0)=0,ode_3,cc(0)=0}, type=numeric);
```

$nsol := \mathbf{proc}(x\_rkf45)\ \ldots\ \mathbf{end\ proc}$

```
> odeplot(nsol,[[t,ca(t)],[t,cb(t)],[t,cc(t)]],0..5,labels=[t,c],legend=[a,b,c],thickness=3);
```




```
> 
```

Vratná reakce A <--> B

```
> restart;with( DEtools ):with( plots ):with (linalg):
```

```
> ode_1:=diff(ca(t),t)=-k_1*ca(t)+k_2*cb(t);
```

$$ode\_1 := \frac{d}{dt}\, ca(t) = -k\_1\, ca(t) + k\_2\, cb(t)$$

```
> ode_2:=diff(cb(t),t)=(k_1)*ca(t)-k_2*cb(t);
```

$$ode\_2 := \frac{d}{dt}\, cb(t) = k\_1\, ca(t) - k\_2\, cb(t)$$

```
> dsolve({ode_1,ca(0)=ca0},ca(t));
```

$$ca(t) = \left(\int_0^t k\_2\, cb(\_z1)\, e^{k\_1\, \_z1}\, d\_z1 + ca0\right) e^{-k\_1\, t}$$

```
> dsolve({ode_2,cb(0)=cb0},cb(t));
```

$$cb(t) = \left(\int_0^t k\_1\, ca(\_z1)\, e^{k\_2\,\_z1}\, d\_z1 + cb0\right) e^{-k\_2\, t}$$

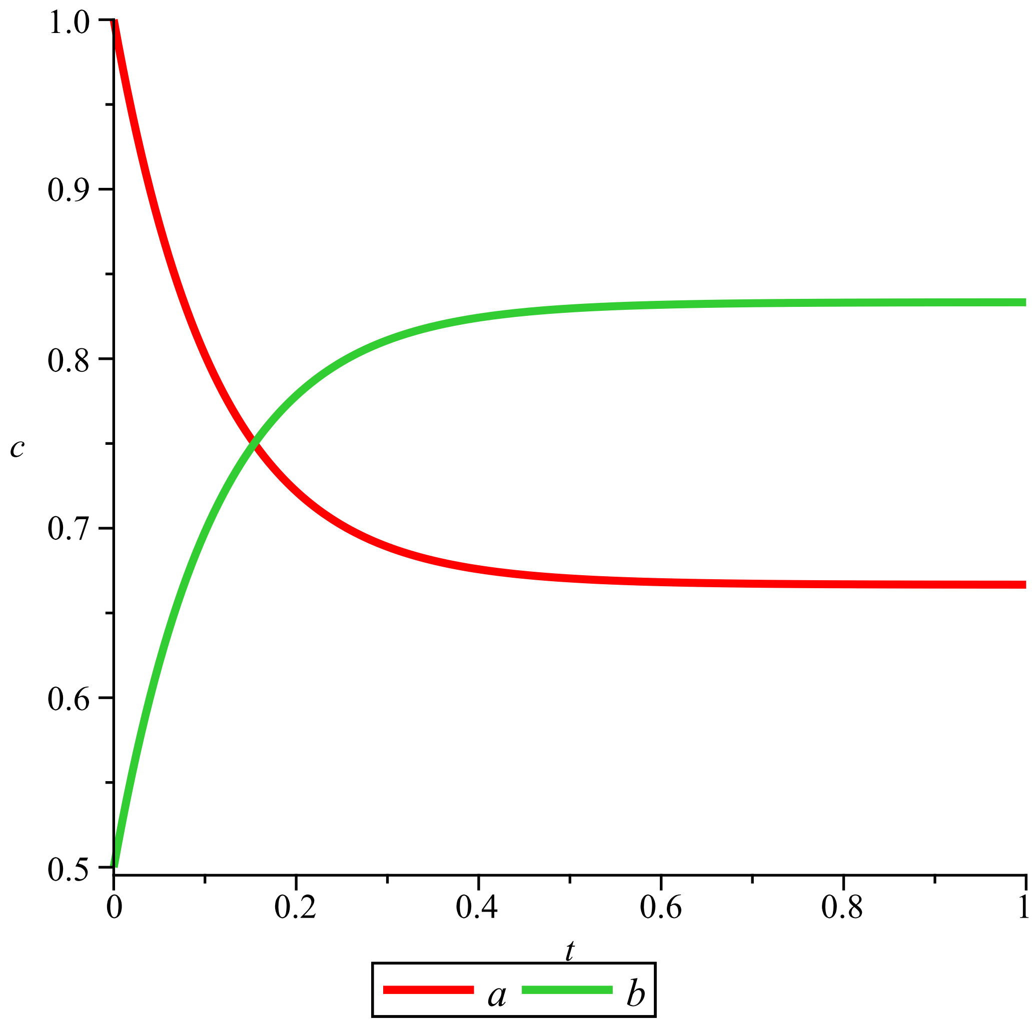
```
> dsolve({ode_1,ca(0)=ca0,ode_2,cb(0)=cb0},{ca(t),cb(t)});
```

$$\left\{ ca(t) = \frac{k\_2\,(cb0+ca0)}{k\_1+k\_2} + \frac{(k\_1\,ca0 - k\_2\,cb0)\, e^{-(k\_1+k\_2)\,t}}{k\_1+k\_2},\ cb(t) = -\frac{(k\_1\,ca0-k\_2\,cb0)\, e^{(-k\_1-k\_2)\,t}}{k\_1+k\_2} + \frac{k\_1\,(cb0+ca0)}{k\_1+k\_2} \right\}$$

```
> k_1:=5:k_2:=4:nsol := dsolve({ode_1,ca(0)=1,ode_2,cb(0)=.5},
  type=numeric);
```

$nsol :=$ **proc**(x_rkf45) ... **end proc**

```
> odeplot(nsol,[[t,ca(t)],[t,cb(t)]],0..1,labels=[t,c],legend=
  [a,b],thickness=3);
```




```
>
```

ešení využívající piblížení

Reakce druheho ádu A+B->C, pevedená na pseudoprvní ád

```
> restart;with( DEtools ):with( plots ):with (linalg ):
> ode_1:=diff(ca(t),t)=-k_1*(ca(t))*(cb(t));
```

$$ode\_1 := \frac{d}{dt}\, ca(t) = -k\_1\, ca(t)\, cb(t)$$

```
> ode_2:=diff(cb(t),t)=-k_1*(ca(t))*(cb(t));
```

$$ode\_2 := \frac{d}{dt}\, cb(t) = -k\_1\, ca(t)\, cb(t)$$

```
> ode_3:=diff(cc(t),t)=k_1*(ca(t))*(cb(t));
```

$$ode\_3 := \frac{d}{dt}\, cc(t) = k\_1\, ca(t)\, cb(t) \qquad \textbf{(9.1.1)}$$

```
> dsolve({ode_1,ca(0)=ca0},ca(t));
```

$$ca(t) = ca0\, e^{\int_0^t (-k\_1\, cb(\_z1))\, d\_z1}$$

```
> dsolve({ode_2,cb(0)=ca0},cb(t));
```

$$cb(t) = ca0\, e^{\int_0^t (-k\_1\, ca(\_z1))\, d\_z1}$$

```
> dsolve({ode_1,ca(0)=ca0,ode_2,cb(0)=cb0,ode_3,cc(0)=cc0},
  {ca(t),cb(t),cc(t)});
```

$$\Bigg\{ ca(t) = \Bigg(\left(e^{I\pi\_Z1\sim}\right)^2 e^{t(-cb0\, k\_1 + k\_1\, ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\, k\_1}\right) + 2 I \pi\_Z2\sim\right)(-cb0\, k\_1 + k\_1\, ca0)}{k\_1(-cb0 + ca0)}} \Big($$

$$-cb0\, k\_1 + k\_1\, ca0\Big)\Bigg) \Bigg/ \Bigg(-1$$

$$+ k\_1\, e^{t(-cb0\, k\_1 + k\_1\, ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\, k\_1}\right) + 2 I \pi\_Z2\sim\right)(-cb0\, k\_1 + k\_1\, ca0)}{k\_1(-cb0 + ca0)}} \Bigg),\ cb(t) =$$

$$-\Bigg(\Bigg(\Big(\left(e^{I\pi\_Z1\sim}\right)^2 (-cb0\, k\_1$$

$$+ k\_1\, ca0)^2\, e^{t(-cb0\, k\_1 + k\_1\, ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\, k\_1}\right) + 2 I \pi\_Z2\sim\right)(-cb0\, k\_1 + k\_1\, ca0)}{k\_1(-cb0 + ca0)}}\Big) \Big/ \Big(-1$$

$$+ k\_1\, e^{t(-cb0\, k\_1 + k\_1\, ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\, k\_1}\right) + 2 I \pi\_Z2\sim\right)(-cb0\, k\_1 + k\_1\, ca0)}{k\_1(-cb0 + ca0)}}\Big)$$

$$\_1\, ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\, k\_1}\right) + 2 I \pi\_Z2\sim\right)(-cb0\, k\_1 + k\_1\, ca0)}{k\_1(-cb0 + ca0)}}\Big)^2\Bigg) \Big(-1$$

$$-$$

$$+ k\_1\, e^{t(-cb0\, k\_1 + k\_1\, ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\, k\_1}\right) + 2 I \pi\_Z2\sim\right)(-cb0\, k\_1 + k\_1\, ca0)}{k\_1(-cb0 + ca0)}}\Big)\Bigg) \Big/$$

$$\Big(k\_1 \left(e^{I\pi\_Z1\sim}\right)^2 e^{t(-cb0\, k\_1 + k\_1\, ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\, k\_1}\right) + 2 I \pi\_Z2\sim\right)(-cb0\, k\_1 + k\_1\, ca0)}{k\_1(-cb0 + ca0)}} ($$

$$-cb0\, k\_1 + k\_1\, ca0)\Big),\ cc(t) =$$

$$-\Big(\left(e^{I\pi\_Z1\sim}\right)^2 e^{t(-cb0\, k\_1 + k\_1\, ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\, k\_1}\right) + 2 I \pi\_Z2\sim\right)(-cb0\, k\_1 + k\_1\, ca0)}{k\_1(-cb0 + ca0)}} (-cb0\, k\_1$$

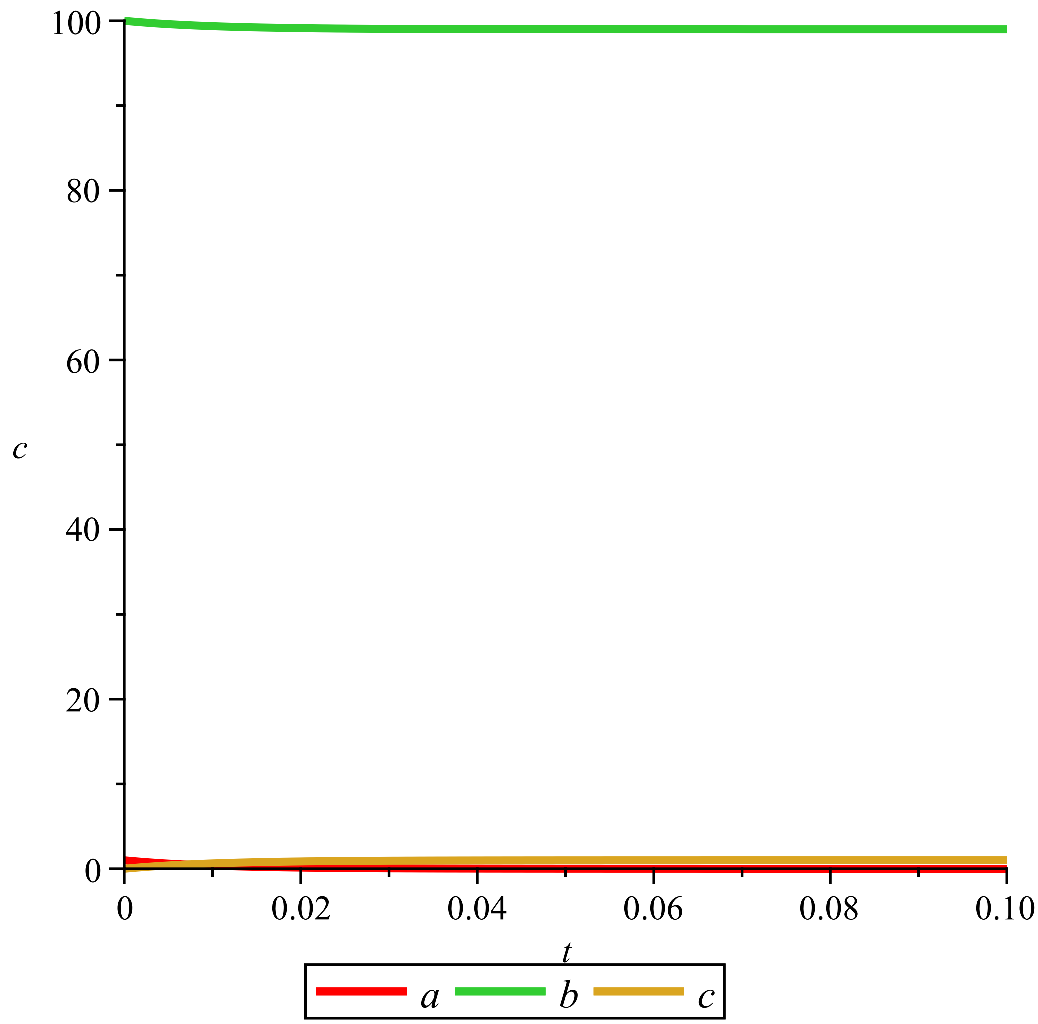
$$+ k\_1\, ca0) \Big) \Big/ \Big(-1$$

$$+ k\_1\, e^{t\,(-cb0\,k\_1 + k\_1\,ca0)}\, e^{\frac{\left(\ln\left(\frac{ca0}{cb0\,k\_1}\right) + 2\,I\,\pi\,\_Z2\sim\right)(-cb0\,k\_1 + k\_1\,ca0)}{k\_1\,(-cb0 + ca0)}} \Big) + ca0 + cc0 \Big\}$$

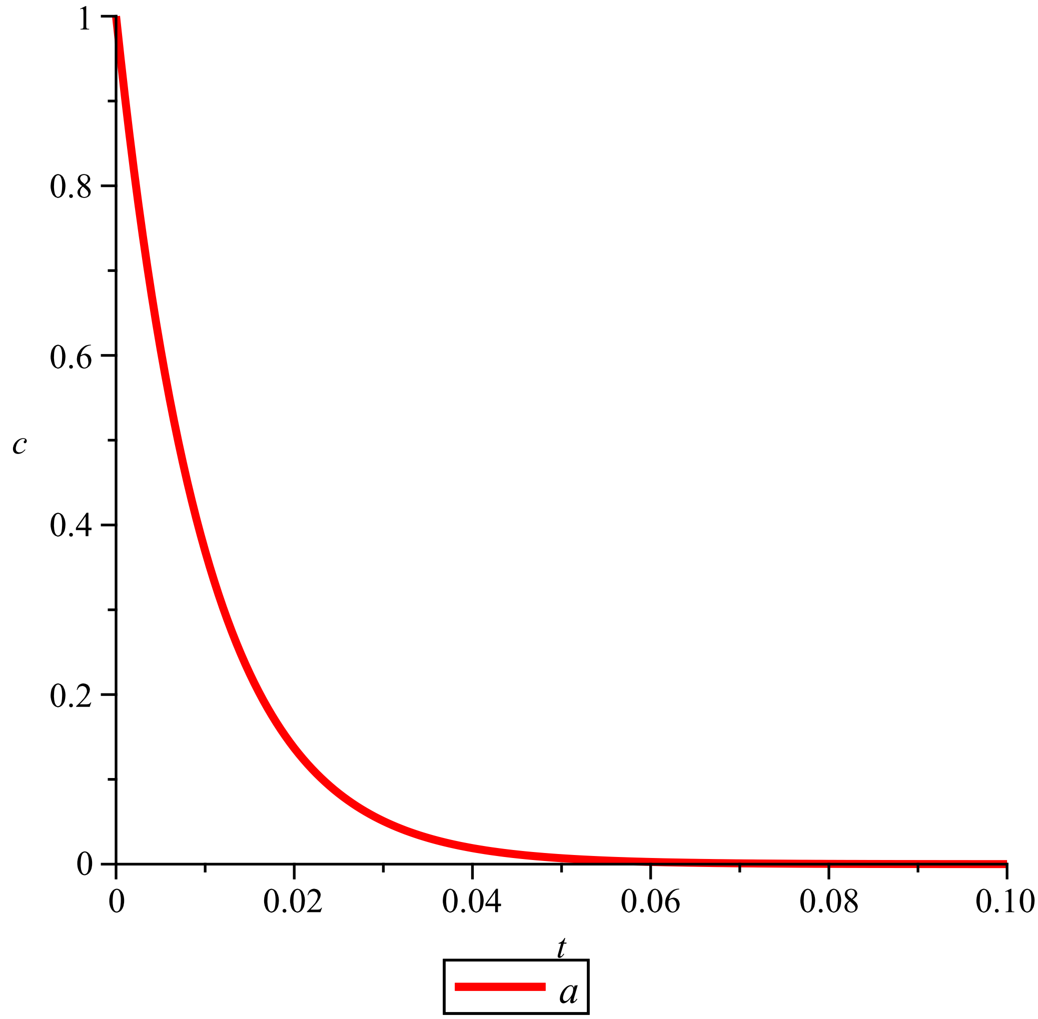
```
> k_1:=1:nsol := dsolve({ode_1,ca(0)=1,ode_2,cb(0)=100,ode_3,
cc(0)=0}, type=numeric);
```

$$nsol := \mathbf{proc}(x\_rkf45)\ \ldots\ \mathbf{end\ proc}$$

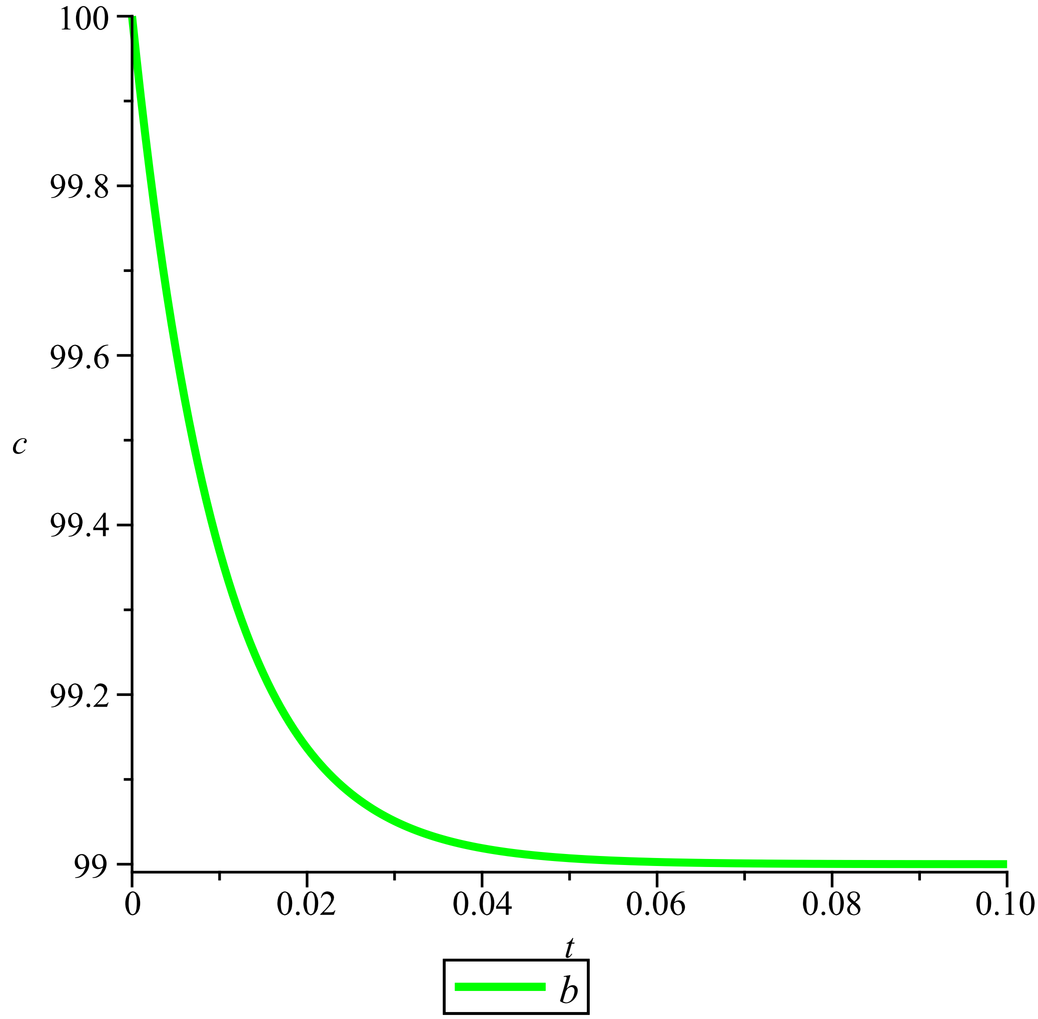
```
> odeplot(nsol,[[t,ca(t)],[t,cb(t)],[t,cc(t)]],0..0.1,labels=
[t,c],legend=[a,b,c],thickness=3);
```




```
> odeplot(nsol,[[t,ca(t)]],0..0.1,labels=[t,c],legend=[a],
thickness=3);
```




```
> odeplot(nsol,[[t,cb(t)]],0..0.1,labels=[t,c],legend=[b],
  thickness=3,color=[green]);
```


100
99.8
99.6
c
99.4
99.2
99
0
0.02
0.04
0.06
0.08
0.10
t
b

>