Acid-Base pH Titration Curves with PSTricks

Version 0.01

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Contents

This work is based on the article by Marc Chapelet: B.U.P. No. 668. [1]

»Titration (also known as titrimetry and volumetric analysis) is a common laboratory method of quantitative chemical analysis to determine the concentration of an identified analyte (a substance to be analyzed). [2, 3] A reagent, termed the titrant or titrator, is prepared as a standard solution of known concentration and volume. The titrant reacts with a solution of analyte (which may also be termed the titrand[3]) to determine the analyte's concentration. The volume of titrant that reacted with the analyte is termed the titration volume.« [4]

1 Presentation

Marc Chapelet's article appeared in the November 1984 issue of the »Bulletin de l'Union des Physiciens«. »*Dosage acide-base à l'aide d'un micro-ordinateur« (Acid-Base Titration Using a Microcomputer).

The commands must be enclosed within a `\begin{pspicture}(-0.5,-0.5)(16,15)...\end{pspicture}` environment. For example:

Command example

```
\begin{pspicture}(-0.5,-0.5)(16,15)
\psTitrationAB[CA=0.0001,CB=0.0001,VA=8.5,unit=0.8,tangentes=true,pH1=4.5]
\end{pspicture}
```

1.1 Titration of a Strong Acid with a Strong Base

The Command

The syntax

```
\psTitrationAB[options]
```

The parameter

Option	*Type*	*Default*	*Description*
VA	number	10	acid volume in mL
CA	number	0.1	concentration of the acid solution in mol/L
CB	number	0.1	concentration of the base solution in mol/L
dpH	boolean	true	plot $\frac{dpH}{dV_B}$
dpHunit	number	1	scale factor for $\frac{dpH}{dV_B}$
Equivalence	boolean	true	marks equivalence point E
valeurs	boolean	false	calculates and places the coordinates
tangentes	boolean	false	tangents boolean false determines E using the tangents method and plots the tangents
pH1	number	5	pH value for the first tangency point
pHstyle	setting	redbold	parameter sequence redbold plot style for pH = f(v_B)
dpHstyle	setting	bluenormal	plot style for the pH derivative with respect to v_B
tangentesstyle	setting	Darkgray	plot style for the tangents

`\newpsstyle`

```
\newpsstyle{redbold}{linecolor=red,linewidth=1.5\pslinewidth}
\newpsstyle{bluenormal}{linecolor=blue}
\newpsstyle{DarkGray}{linecolor=darkgray}
```

1.2 Titration of a Strong Base with a Strong Acid

The command

Syntax of \psTitrationBA

```
\psTitrationBA[options]
```

Parameters

These are identical to those for the titration of a strong acid with a strong base; the initial value of VB must be specified.

Option	*Type*	*Default*	*Description*
VB	number	10	Base volume (in mL)
CA	number	0.1	Acid solution concentration (in mol/L)
CB	number	0.1	Basic solution concentration (in mol/L)

1.3 Titration of a Weak Monoacid with a Strong Base

The command

Syntax of \psTitrationAfBF

```
\psTitrationAfBF[options]
```

Parameters

As with the previous ones, the acid's pK_A must be specified.

Option	*Type*	*Default*	*Description*
VA	number	10	Acid volume (in mL)
CA	number	0.1	Acid solution concentration (in mol/L)
CB	number	0.1	Base solution concentration (in mol/L)
pKA	number	4.75	pK_A of the weak acid

1.4 Titration of a Weak Monobase with a Strong Acid

The Command

Syntax of \psTitrationBfAF

```
\psTitrationBfAF[options]
```

Parameters

Identical to the previous ones; specify the volume of the base being titrated and its corresponding pKB value.

Option	*Type*	*Default*	*Description*
VB	number	10	Volume of acid in mL
CA	number	0.1	Concentration of the acid solution in mol/L

CB	number	0.1	Concentration of the basic solution in mol/L
pKB	number	4.75	pK_A of the weak acid

1.5 Titration of a Triacid with a Strong Base

The command

Syntax of \psTitrationtriacide

```
\psTitrationtriacide[options]
```

Paremeters

Identical to the previous ones; specify the volume of the acid being titrated and the pK_A values for the different acidic steps.

Option	*Type*	*Default*	*Description*
VA	number	10	Volume of acid in mL
CA	number	0.1	Concentration of the acid solution in mol/L
CB	number	0.1	Concentration of the basic solution in mol/L
pKA1	number	2.1	pK_{A1}
pKA2	number	7.2	pK_{A2}
pKA3	number	12	pK_{A3}

2 Examples

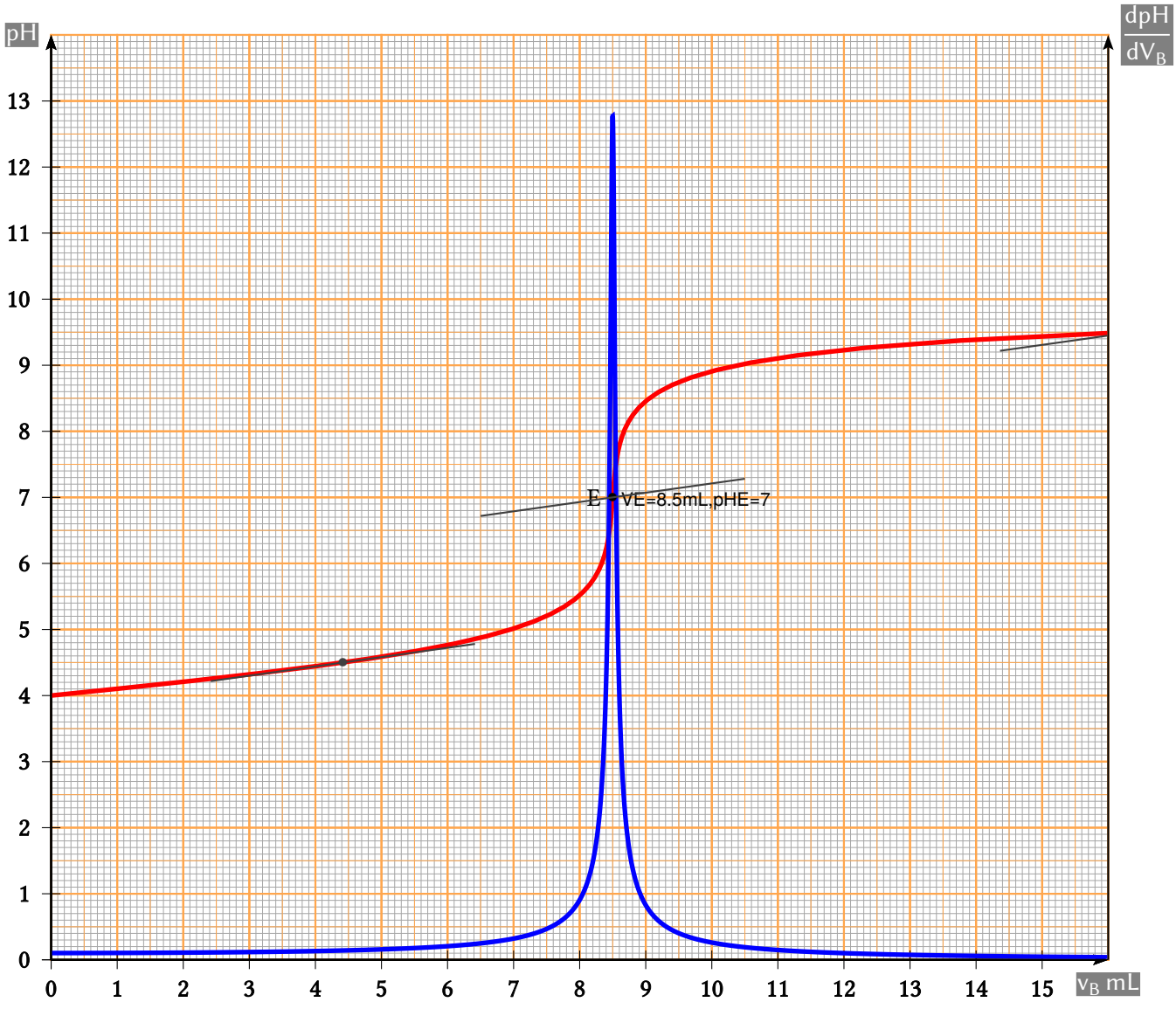
2.1 Titration of a strong acid (molar concentration C_A, volume V_A) with a strong base of concentration C_B.

With $\text{pH} = f(V_B)$ and $\dfrac{\text{dpH}}{\text{d}V_B} = g(V_B)$. $x = [\text{H}_3\text{O}^+]$.

$$V_B = V_A \frac{C_A + \dfrac{K_e}{x} - x}{C_B + x - \dfrac{K_e}{x}}$$

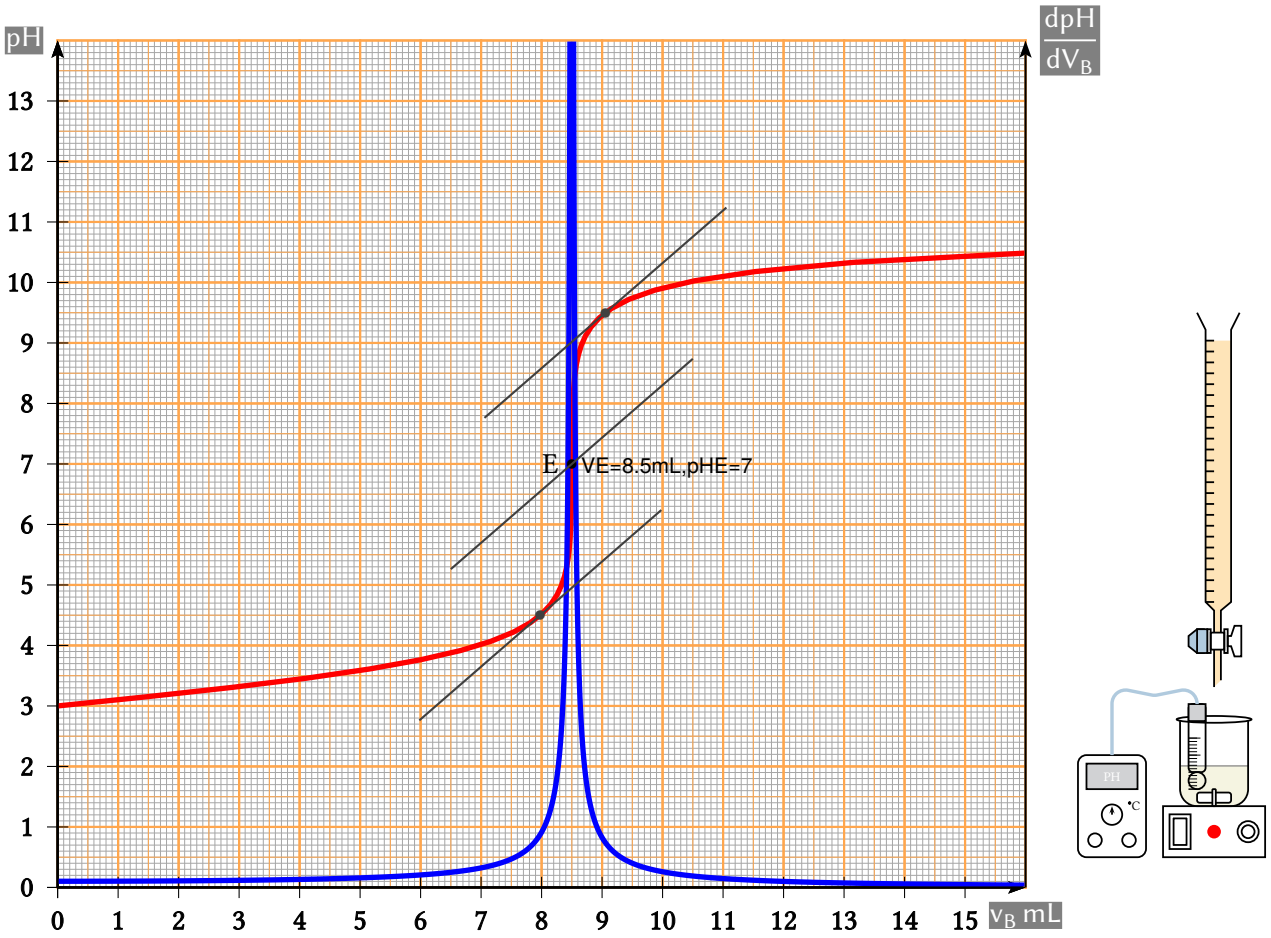
$x = [\text{H}_3\text{O}^+]$

```
\begin{pspicture}(-0.5,-0.5)(16,15)
\psTitrationAB[CA=0.0001,CB=0.0001,VA=8.5,tangentes=true,pH1=4.5]
\end{pspicture}
```



with \pstDosage

```
\begin{pspicture}(-0.5,-0.5)(16,15)
\psTitrationAB[CA=0.001,CB=0.001,VA=8.5,unit=0.8,tangentes=true,pH1=4.5]
\end{pspicture}
\hspace{-3cm}\psscalebox{0.5}{%
  \pstDosage[glassType=becher,phmetre=true,niveauReactifBurette=25,niveauLiquide1=40,
             aspectLiquide1=ChampagneSurface]}
```



At the equivalence point:

$$V_B = \frac{C_A V_A}{C_B} \quad ; \quad \text{pH} = 7$$

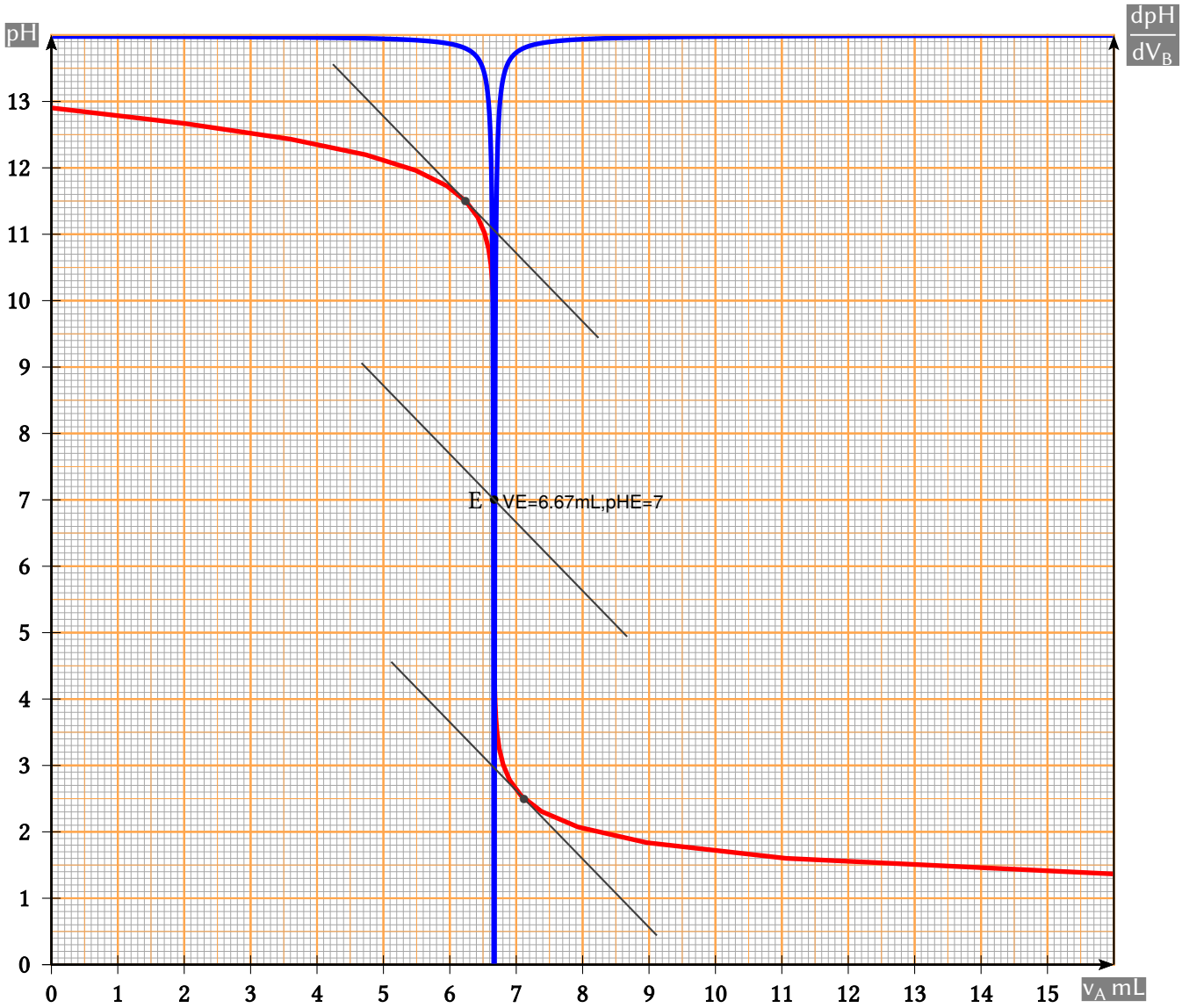
2.2 Titration of a strong base of concentration CB and volume VB with a strong acid of molar concentration CA.

With $\text{pH} = f(V_A)$ and $\dfrac{\text{dpH}}{\text{d}V_A} = g(V_A)$.

$$V_A = V_B \frac{\dfrac{K_e}{x} - x - C_B}{x - \dfrac{K_e}{x} - C_A}$$

Titration of a strong base

```
\begin{pspicture}(-0.5,-0.5)(16,15)
\psTitrationBA[dpHunit=0.2,CA=0.12,CB=0.08,pH1=11.5,tangentes=true]
\end{pspicture}
```



At the equivalence point:

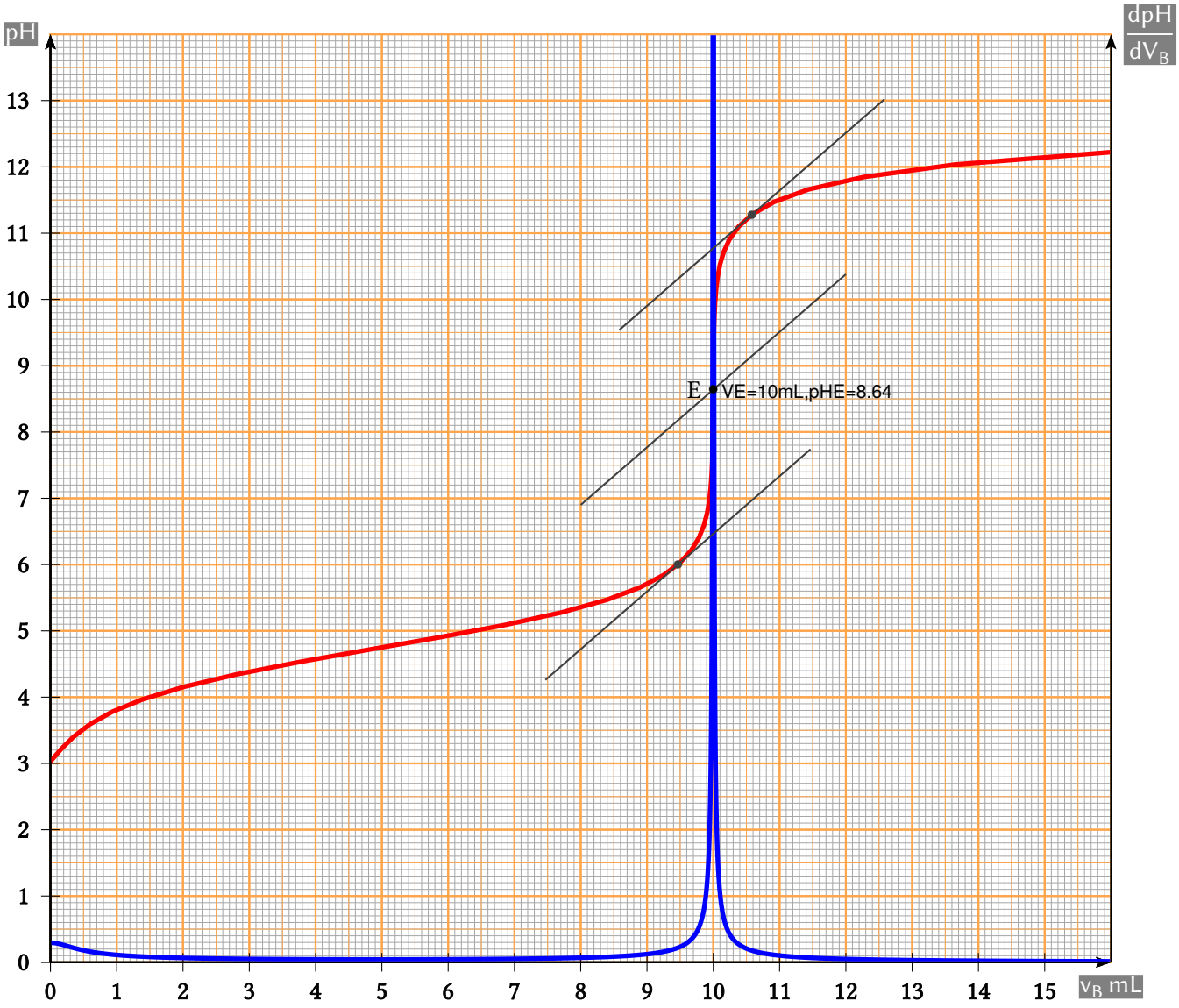
$$V_A = \frac{C_B V_B}{C_A} \quad ; \quad \text{pH} = 7$$

2.3 Titration of a weak acid—with molar concentration CA and volume VA, and whose pKA is given—by a strong base of concentration CB, where $x = [H_3O^+]$

$$V_B = V_A \frac{\frac{C_A}{\frac{x}{K_A}+1} + \frac{K_e}{x} - x}{C_B + x - \frac{K_e}{x}}$$

```
\psTitrationAfBF
```

```
\begin{pspicture}(-0.5,-0.5)(16,15)
\psTitrationAfBF[pKA=4.75,VA=20,CB=0.1,CA=0.05,dpHunit=0.25,pH1=6,tangentes=true]
\end{pspicture}
```



At the equivalence point:

$$V_B = \frac{C_A V_A}{C_B} \quad ; \quad pH = 7 + \frac{1}{2}pK_A + \frac{1}{2}\log\left(\frac{C_A C_B}{C_A + C_B}\right)$$

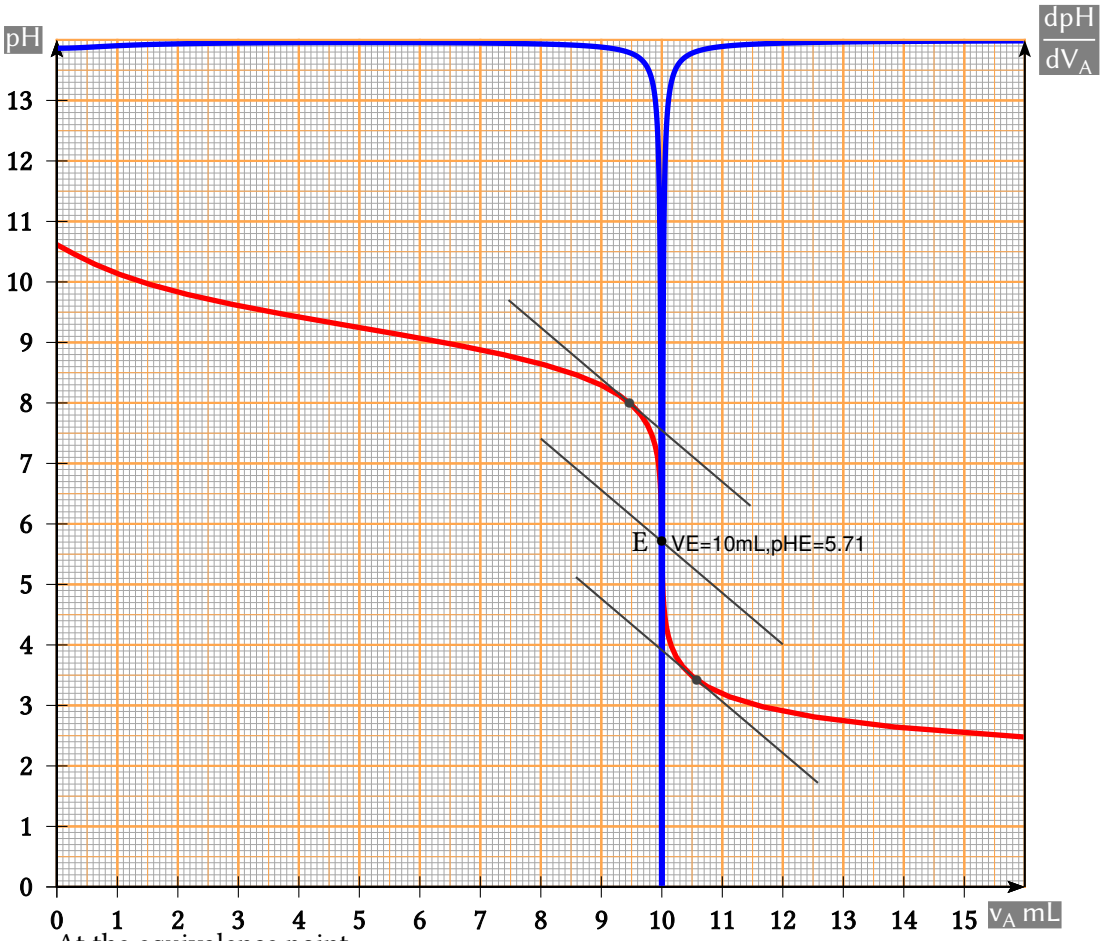
2.4 Titration of a weak base—of molar concentration C_B and volume V_B, for which the pK_B is given with a strong acid of concentration C_A.

$$V_A = V_B \frac{\dfrac{C_A}{1+\dfrac{K_e}{xK_B}} - \dfrac{K_e}{x} + x}{C_A + \dfrac{K_e}{x} - x}$$

\psTitrationBfAF

```
\begin{pspicture}(-0.5,-0.5)(16,15)
\psTitrationBfAF[pKB=4.75,VB=20,CB=0.01,CA=0.02,dpHunit=0.25,tangentes=true,pH1=8]
\end{pspicture}
```

2.5 pH Variation Curve: Ammonia/Hydrochloric Acid



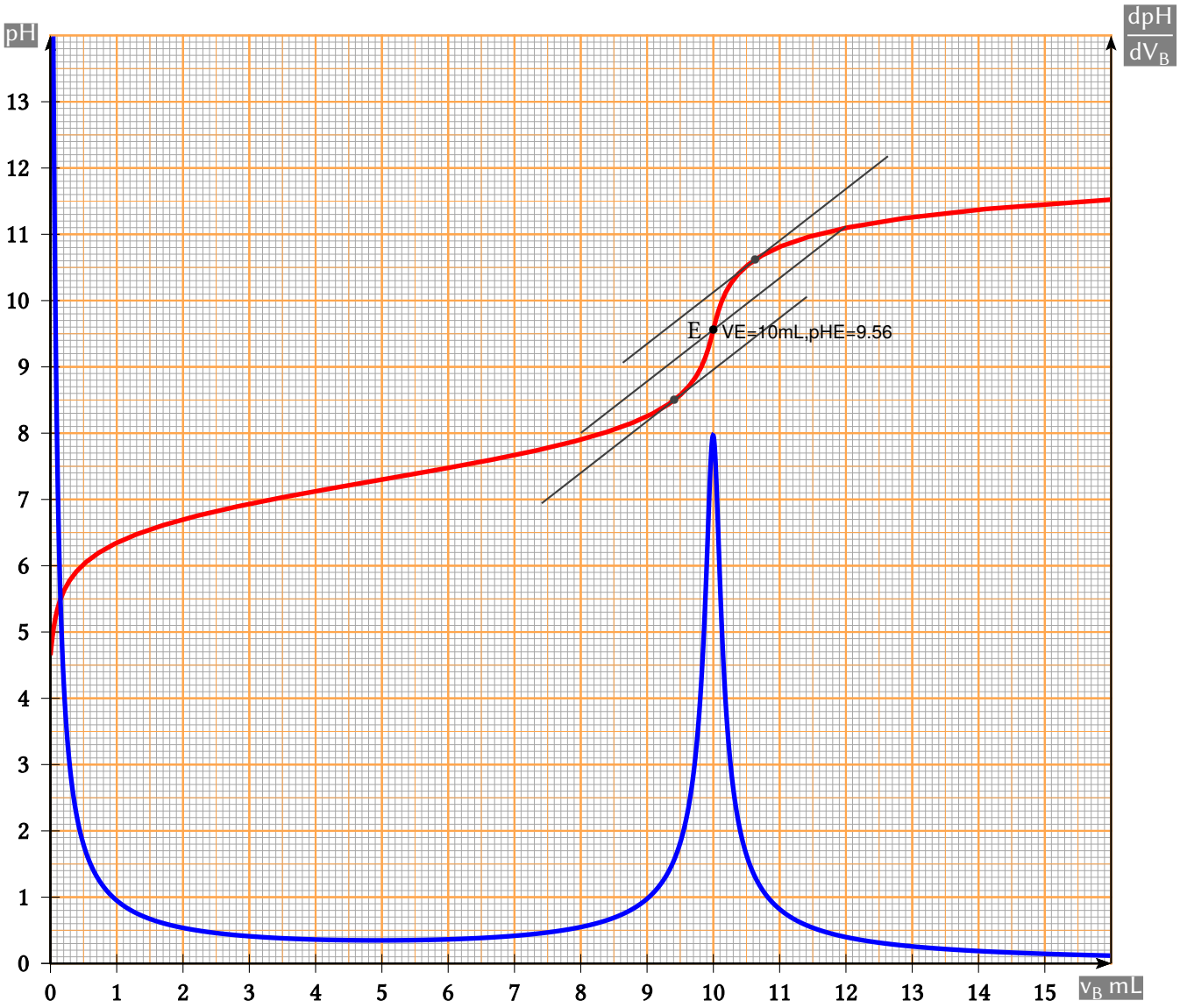
At the equivalence point:

$$V_A = \frac{C_B V_B}{C_A} \quad ; \quad pH = 7 - \frac{1}{2}pK_B - \frac{1}{2}\log\left(\frac{C_A C_B}{C_A + C_B}\right)$$

2.6 Another example of the titration of a weak acid with a strong base.

\psTitrationAfBF

```
\begin{pspicture}(-0.5,-0.5)(16,15)
\psTitrationAfBF[pKA=7.3,VA=20,CB=0.02,CA=0.01,dpHunit=2,pH1=8.5,tangentes=true]
\end{pspicture}
```



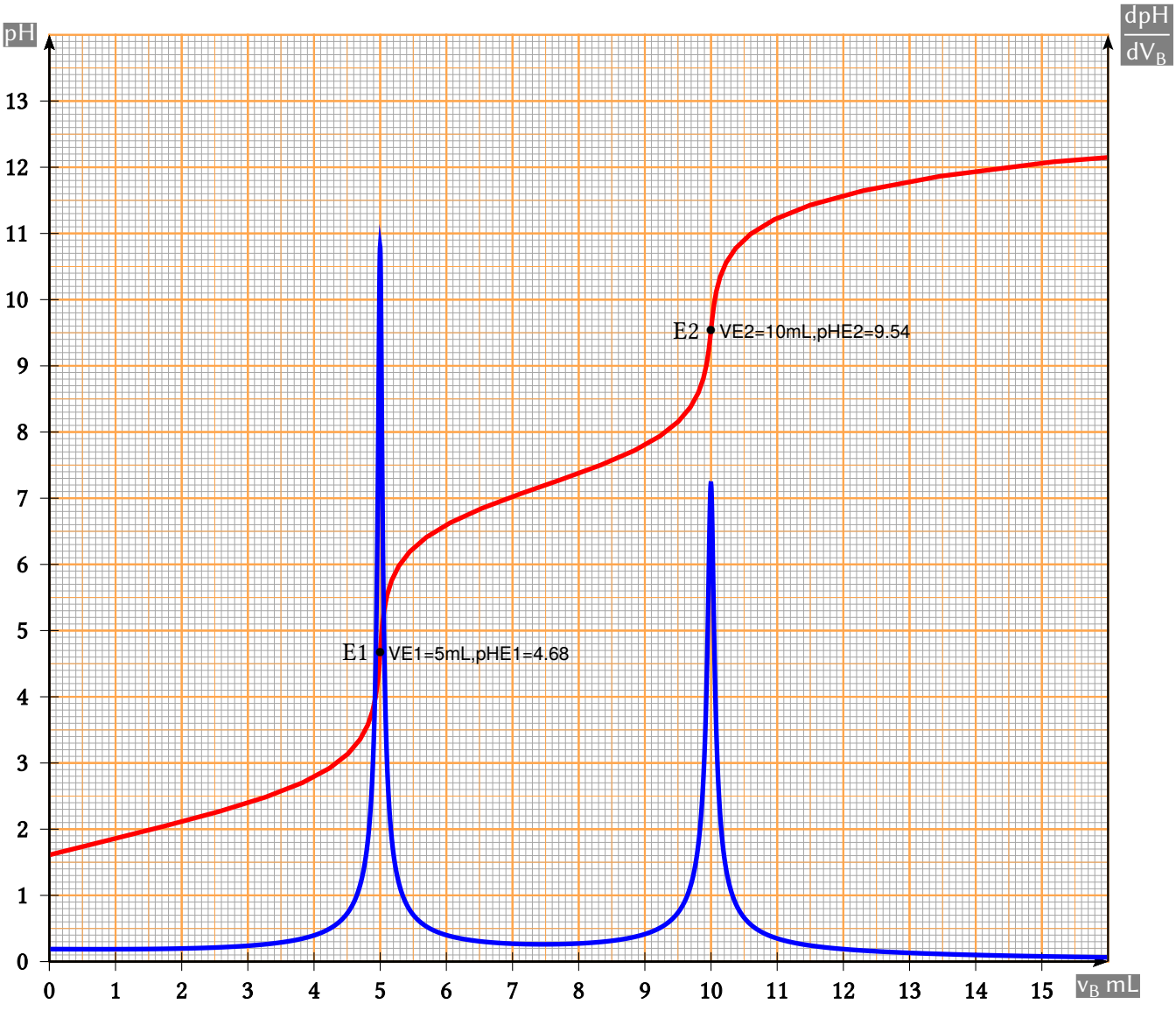
2.7 Titration of a triacid AH_3 of molar concentration C_A and volume V_A, with acidity constants K_{A1}, K_{A2}, and K_{A3} by a strong base B of concentration C_B

$$V_B = V_A \frac{C_A \frac{\left(1+\frac{2K_{A1}}{x}+\frac{3K_{A2}K_{A3}}{x^2}\right)}{\left(\frac{x}{K_{A1}}+1+\frac{K_{A2}}{x}+\frac{K_{A2}K_{A3}}{x^2}\right)} + \frac{K_e}{x} - x}{x - \frac{K_e}{x} + C_B}$$

```
\psTitrationtriacide
```

```
\begin{pspicture}(-0.5,-0.5)(16,15)
\psTitrationtriacide[VA=5,dpHunit=0.75]
\edn{pspicture}
```

2.8 Determination of Phosphoric Acid using Sodium Hydroxide



3 Changing the Graph Paper

You can redefine the graph paper that was initially defined by:

\graphpaper

```
\newcommand\graphpaper{%
   \psset{gridwidth=1\pslinewidth}
   \psgrid[gridlabels=0,subgriddiv=10,subgridwidth=0.1\pslinewidth,subgridcolor=gray,gridcolor=orange](16,14)%
   \psgrid[gridlabels=0,subgriddiv=2,subgridwidth=0.4\pslinewidth,subgridcolor=orange,gridcolor=orange](16,14)%
   \psset{arrowscale=1.5,arrowinset=0.2}%
   \uput[l](0,14){\cadregris{\textsf{pH}}}%
   \psaxes{->}(16,14)}
```

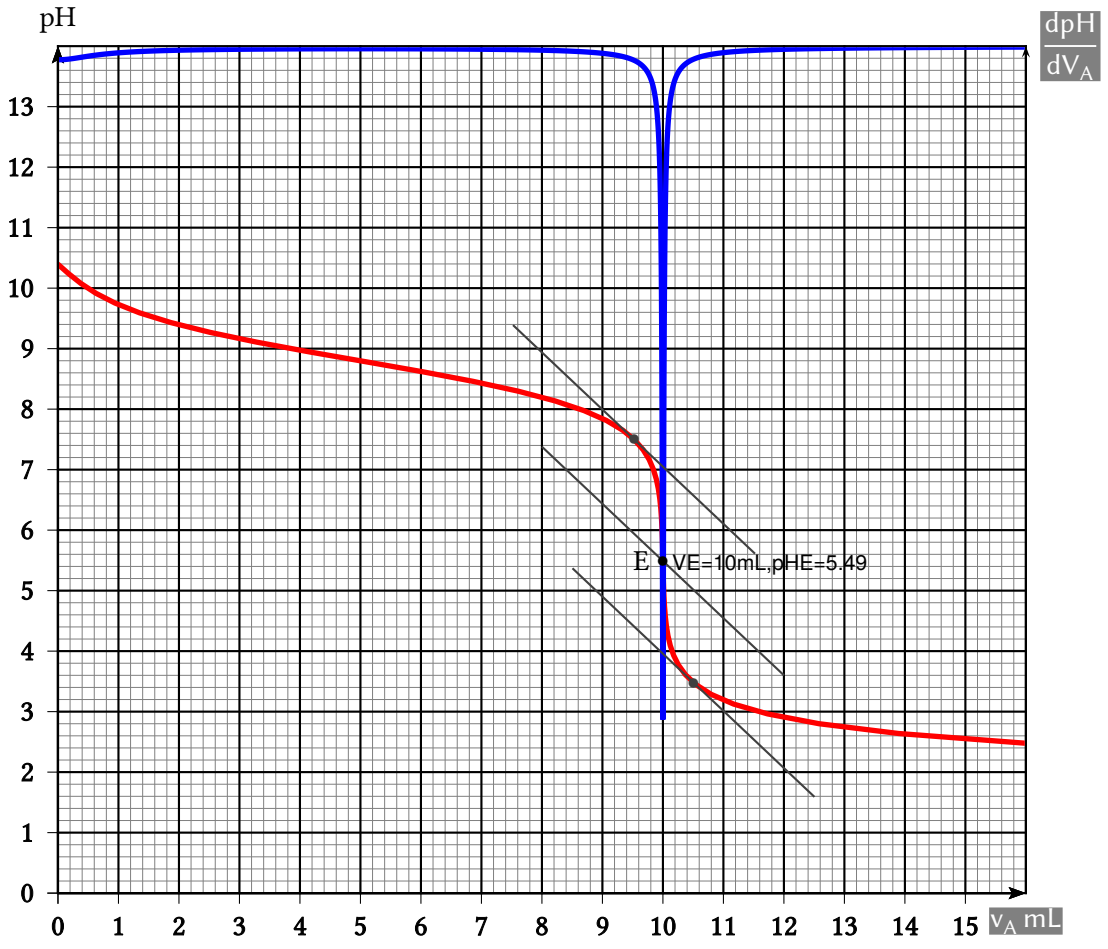
By writing, for example::

\graphpaper

```
\renewcommand\graphpaper{%
   \psgrid[subgridwidth=0.2\pslinewidth,gridlabels=0pt](16,14)%
   \psaxes[arrowscale=1.5,arrowinset=0.2}]{->}(15,14)}[{},0][pH,90]
```

\psTitrationBfAF

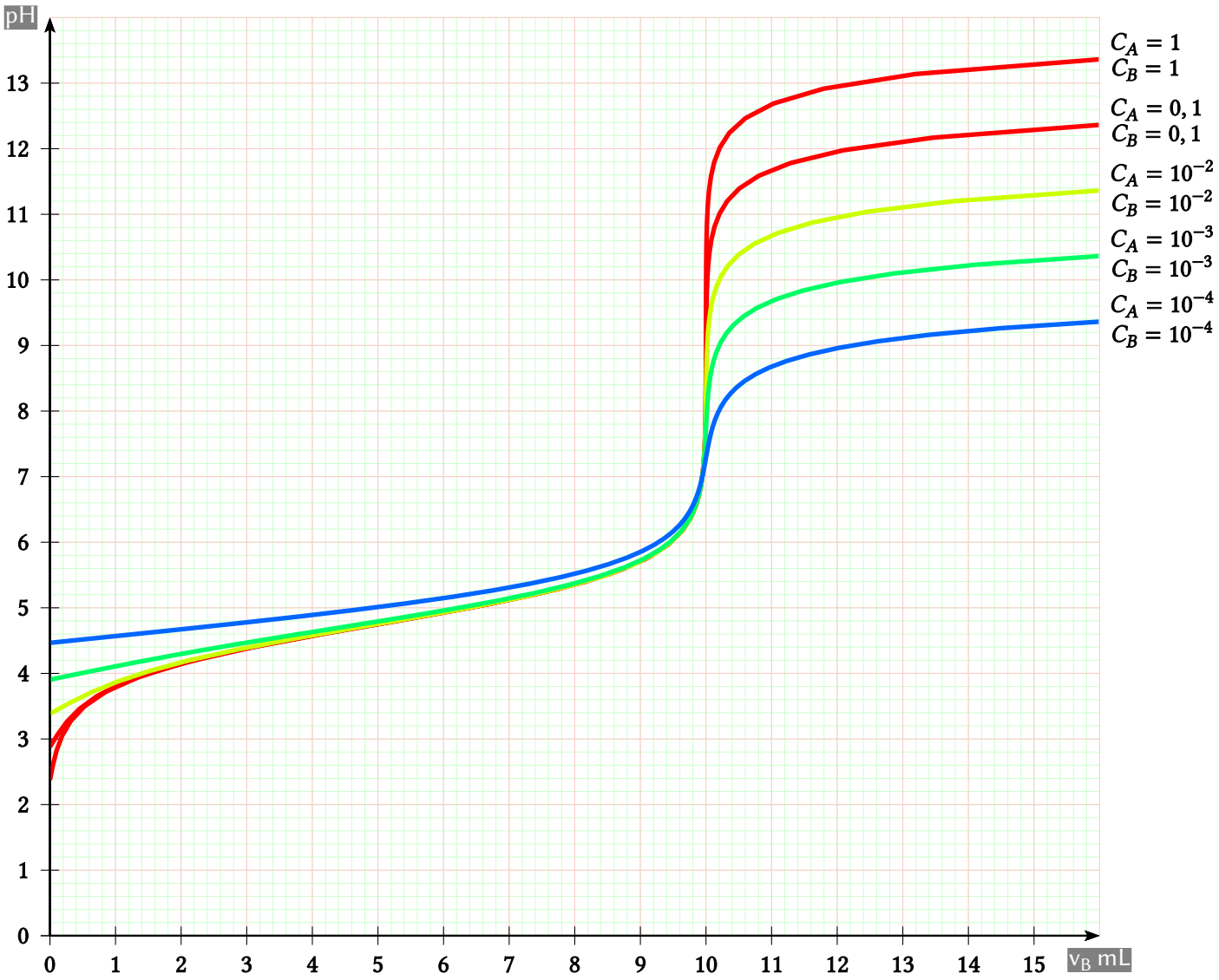
```
\psTitrationBfAF[pKB=5.2,VB=20,CB=0.01,CA=0.02,dpHunit=0.25,tangentes=true,pH1=7.5]%
```



4 Superimposing different curves

\psTitrationAfBF

```
\begin{pspicture}(-0.5,-0.5)(16,15)
\psset{pKA=4.75,VA=10,dpH=false,Equivalence=false,pH1=6,tangentes=false}
\psTitrationAfBF[CB=1,CA=1]
\renewcommand\graphpaper{}%
\multido{\i=-1+-1}{4}{%
\psTitrationAfBF[CB=10 \i\space exp,CA=10 \i\space exp]}
\end{pspicture}
```

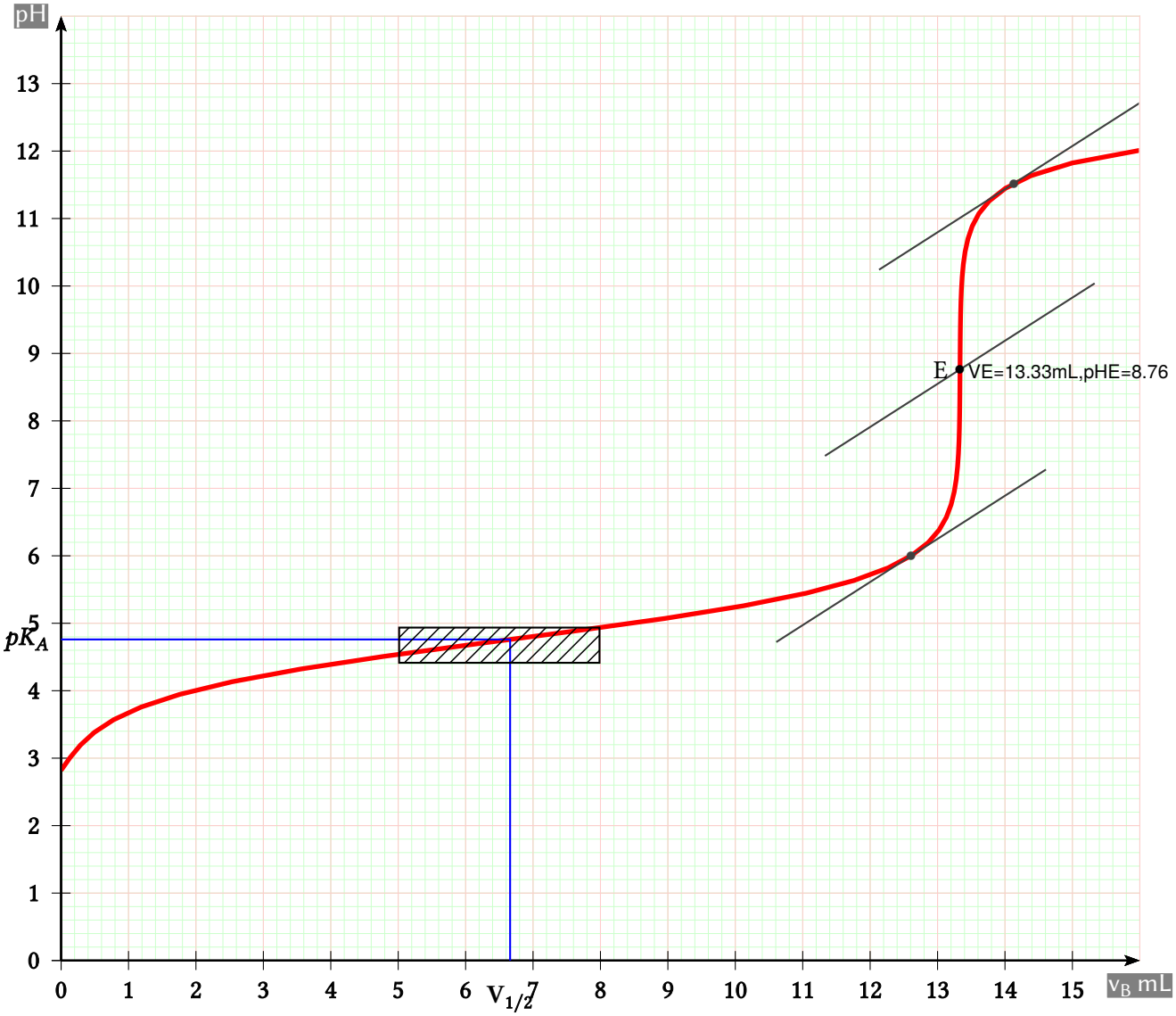


5 Observations on a Graph

Titration of a 1:10 diluted vinegar solution with a sodium hydroxide solution. Demonstration of the buffer region around the half-equivalence point.

\psTitrationAfBF

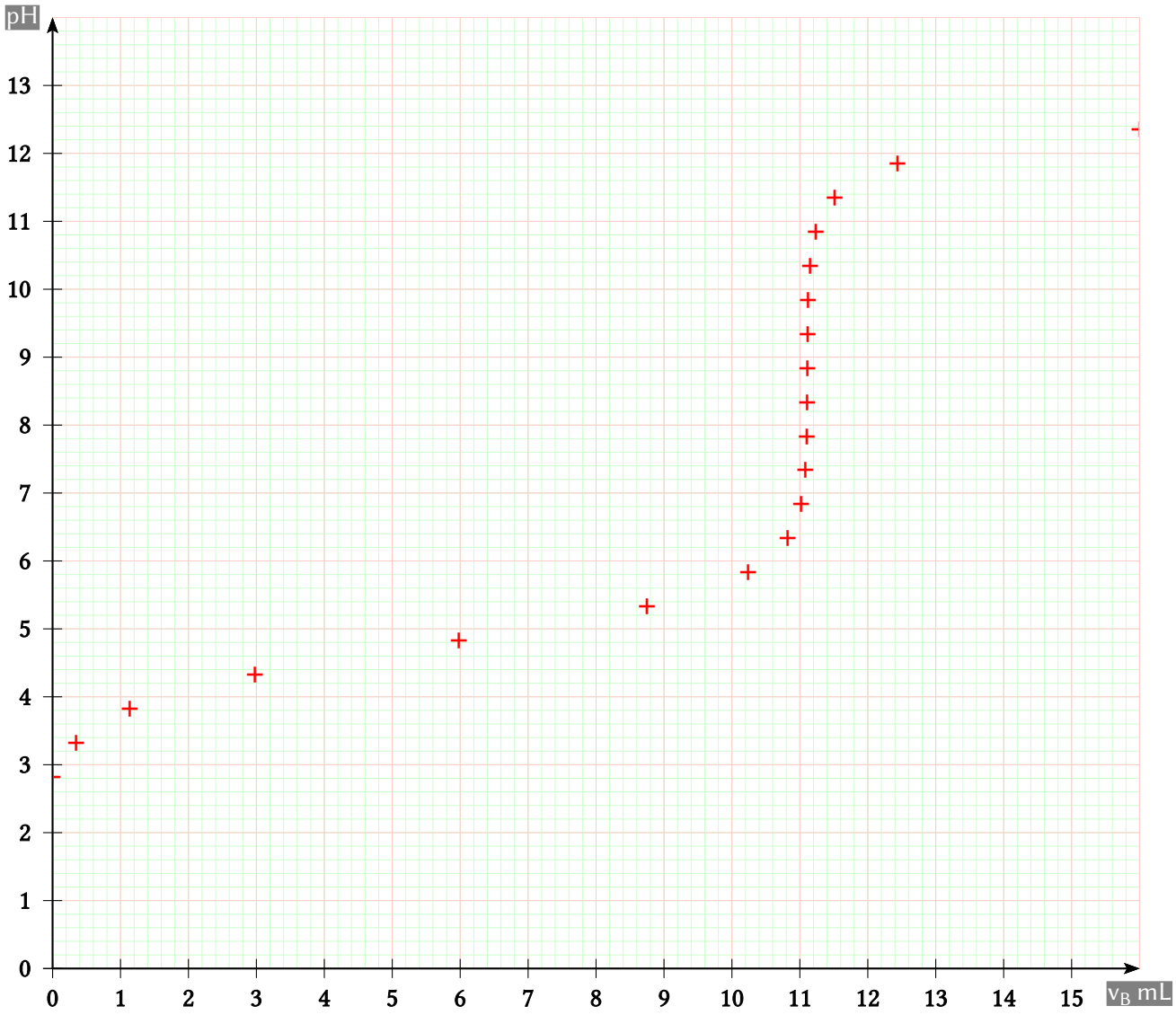
```
\begin{pspicture}(-0.5,-0.5)(16,15)
\psTitrationAfBF[CA=0.133333,CB=0.1,VA=10,dpH=false,pKA=4.76,valeurs,tangentes,pH1=6]
\psline[linecolor=blue](0,4.76)(6.66,4.76)(6.66,0)
\uput[l](0,4.76){$pK_A$}
\uput[d](6.66,-0.2){$\mathbf{V_{1/2}}$}
\psframe[fillstyle=hlines,hatchwidth=0.02](5,4.4)(8,4.95)
```



6 Marking a curve using only points

\psTitrationAfBF

```
\begin{pspicture}(-0.5,-0.5)(16,15)
\newpsstyle{despoints}{showpoints,linecolor=red,linewidth=3\pslinewidth}
\psTitrationAfBF[pHstyle=despoints,CA=0.133333,CB=0.12,VA=10,dpH=false,pKA=4.76,
            Equivalence=false,plotpoints=20,linestyle=none,dotstyle=B+]
```



References

[1] Marc Chapelet. “Dosage acide-base à l’aide d’un micro-ordinateur”. In: 79.668 (1) (Nov. 1984). URL: http://materiel-physique.ens-lyon.fr/Logiciels/CD%20N%C2%B0%203%20BUP%20DOC%20V%204.0/Disk%202/TEXTES/1984/06680257.PDF (visited on 05/24/2026).

[2] Jim Clark. *pH (TITRATION) CURVES*. Nov. 2013. URL: https://www.chemguide.co.uk/physical/acidbaseeqia/phcurves.html (visited on 05/25/2026).

[3] Thomas Kraska. *Titration curves – Calculation of titration curves*. University of Cologne – Faculty of Mathematics and Natural Sciences. May 5, 2026. URL: https://van-der-waals.pc.uni-koeln.de/en/applied-chemistry-education/titration-curves (visited on 05/25/2026).

[4] *Titration*. Wikipedia. May 24, 2026. URL: https://en.wikipedia.org/wiki/Titration (visited on 05/24/2026).