Planteamiento del sistema en estudio:

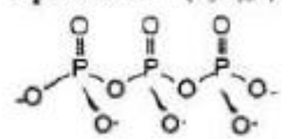
Introducción

Análisis de detergentes

Los detergentes estan elaborados con el tensoactivo dodecil-bencensulfonato de sodio como principio activo. Las sales de calcio y de magnesio de este tensoactivo son mucho mas *solubles* que sus correspondientes sales de ácidos grasos que conforman el principio activo de los jabones comunes, por lo que la dureza del agua no presenta problema para los detergentes. Sin embargo, los iones calcio y magnesio en solución interfieren con las llamadas repulsiones de la doble capa eléctrica que ayudan a los tensoactivos a desprender la suciedad de los sustratos. Dichos iones también afectan la potencia para suspender la suciedad. Consecuentemente los iones Mg(II) y Ca(II) deben eliminarse para lograr una limpieza efectiva. Un *ablandador* usual es el EDTA pero es poco eficiente y caro. El ablandador de elección para uso comercial es el tripolifosfato de sodio que cristaliza en condiciones apropiadas de una mezcla de fosfato disódico y fosfato monosódico:

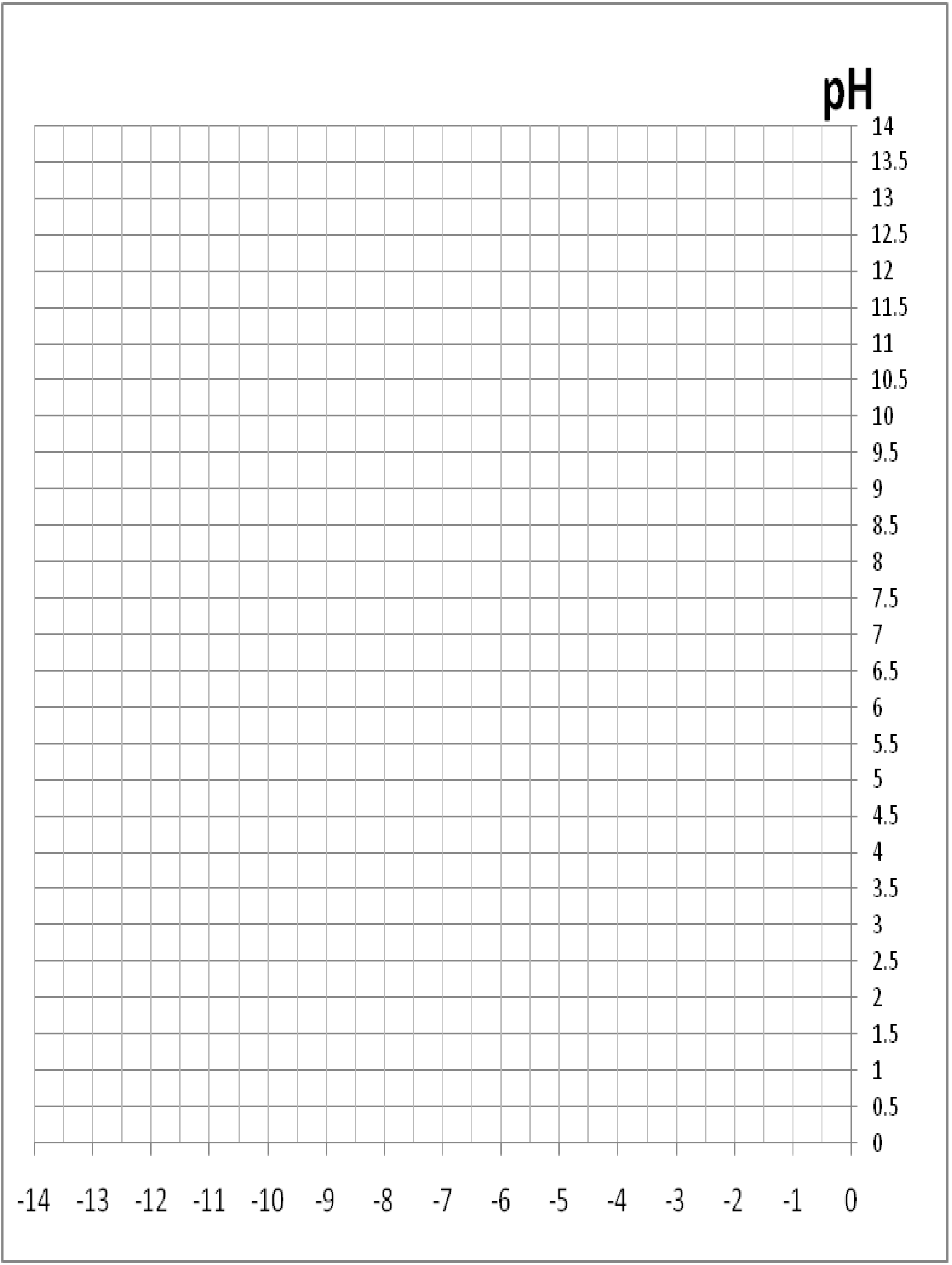
$$2Na_2HPO_4 + NaH_2PO_4 \rightarrow Na_5P_3O_{10} + 2H_2O$$

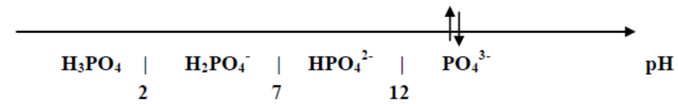
tripolifosfato = ($P_3O_{10}^{5-}$):

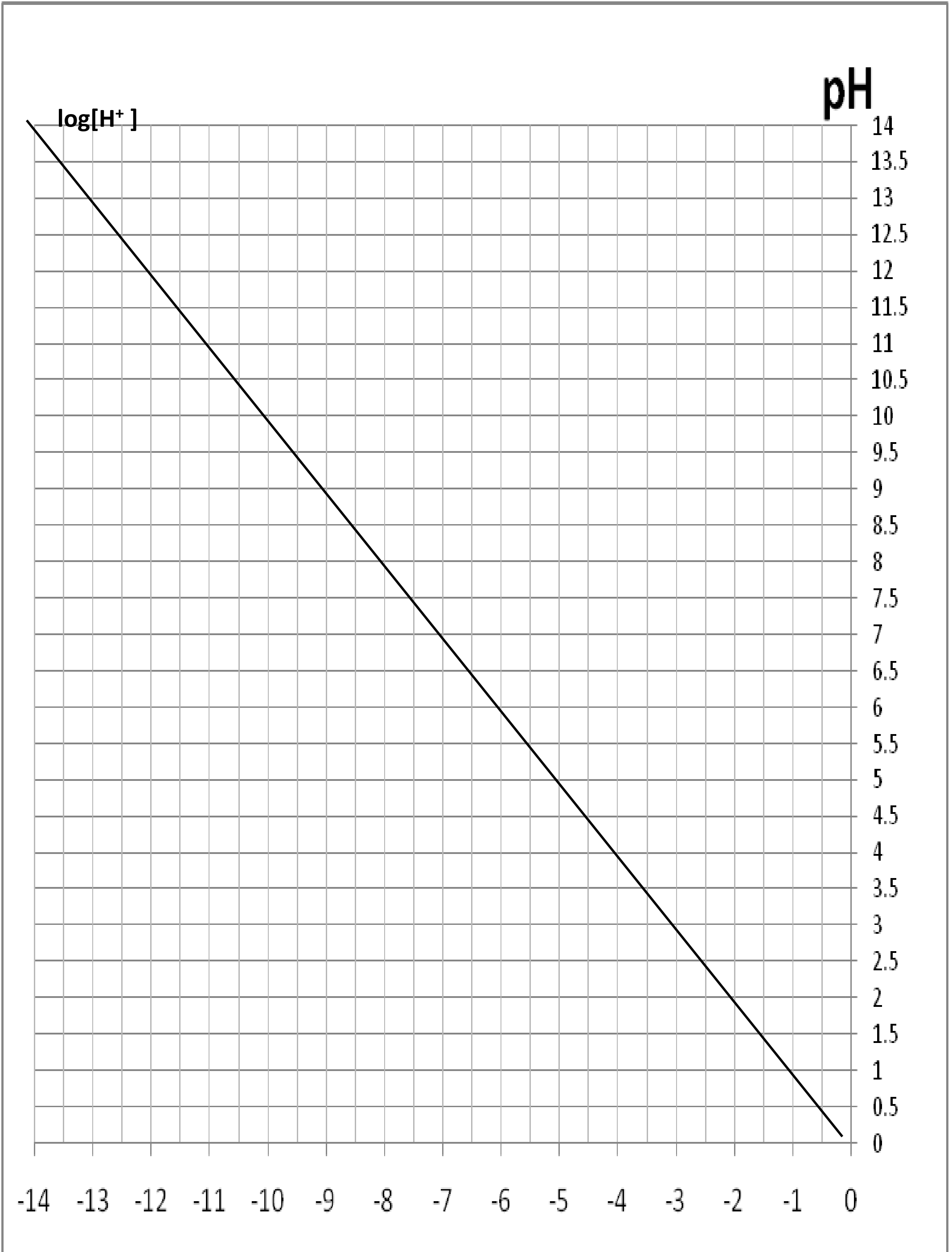


Además de secuestrar a los iones metálicos polivalentes, el tripolifosfato de sodio evita la redeposición de suciedad sobre la superficie por un mecanismo de distribución de cargas por regulación del pH entre 9 y 10. Es además bactericida. El pirofosfato de sodio, $Na_4P_2O_7$ es también usado como quelante. Estos compuestos se conocen como fortificadores de los detergentes[1].

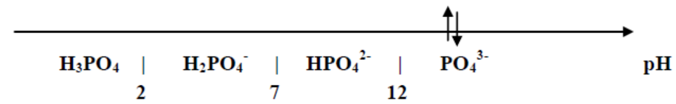
La determinación por métodos químicos de análisis puede ser; a) gravimétrica por precipitación de $Mg_2P_2O_7$y posterior pesada; b) titulométrica con monitoreo potenciométrico del punto de equivalencia experimental, pH =f(v), con una reacción de precipitación de fosfato de Ca(II) y nivelación del $Na_2H_2PO_4$ después de hidrolizar el tripolifosfato[2,3].


pH
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0

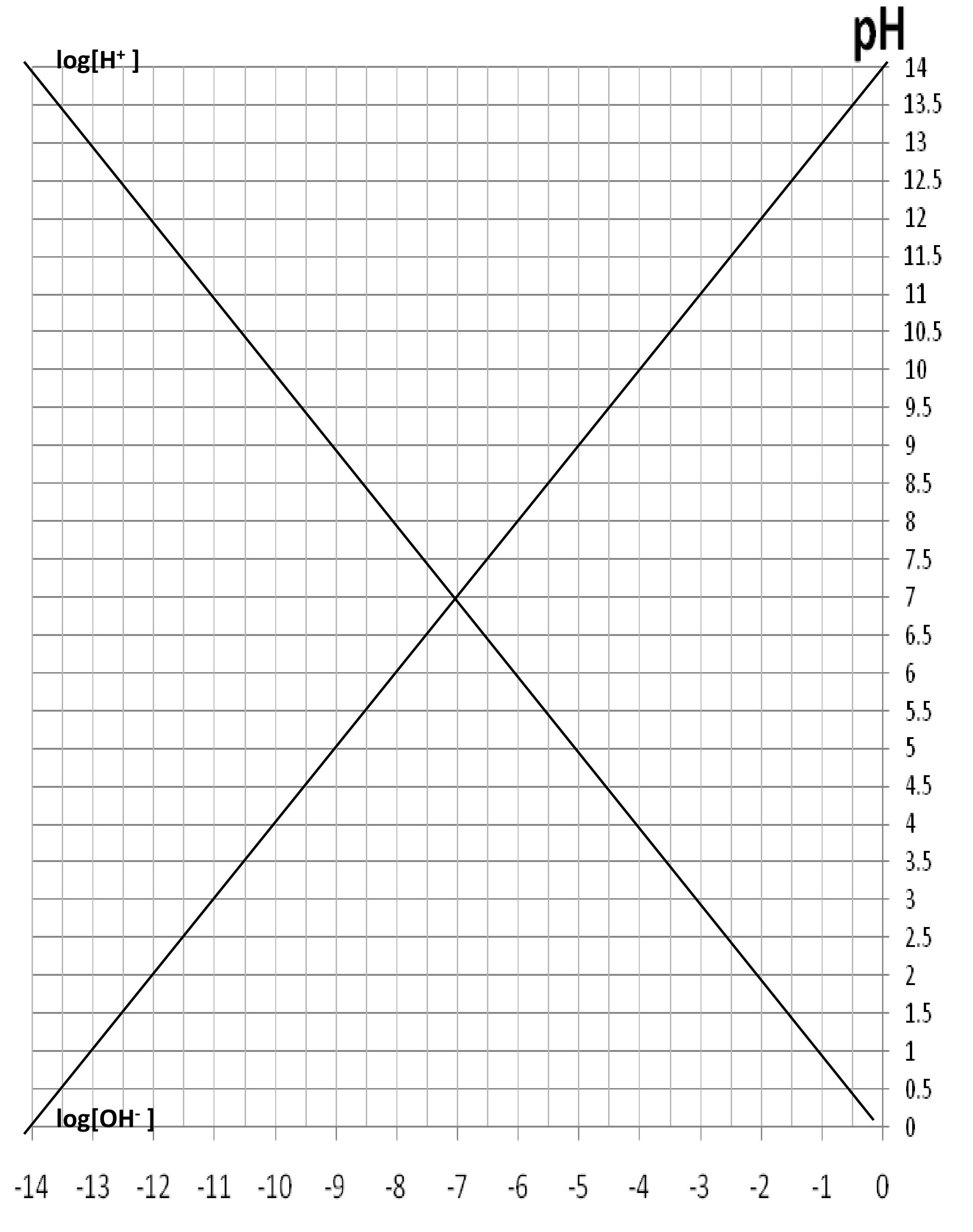

H_3PO_4
$H_2PO_4^-$
HPO_4^{2-}
PO_4^{3-}
pH
2
7
12

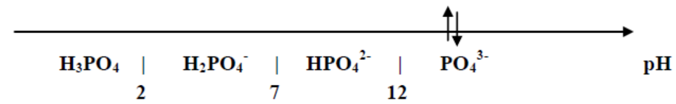


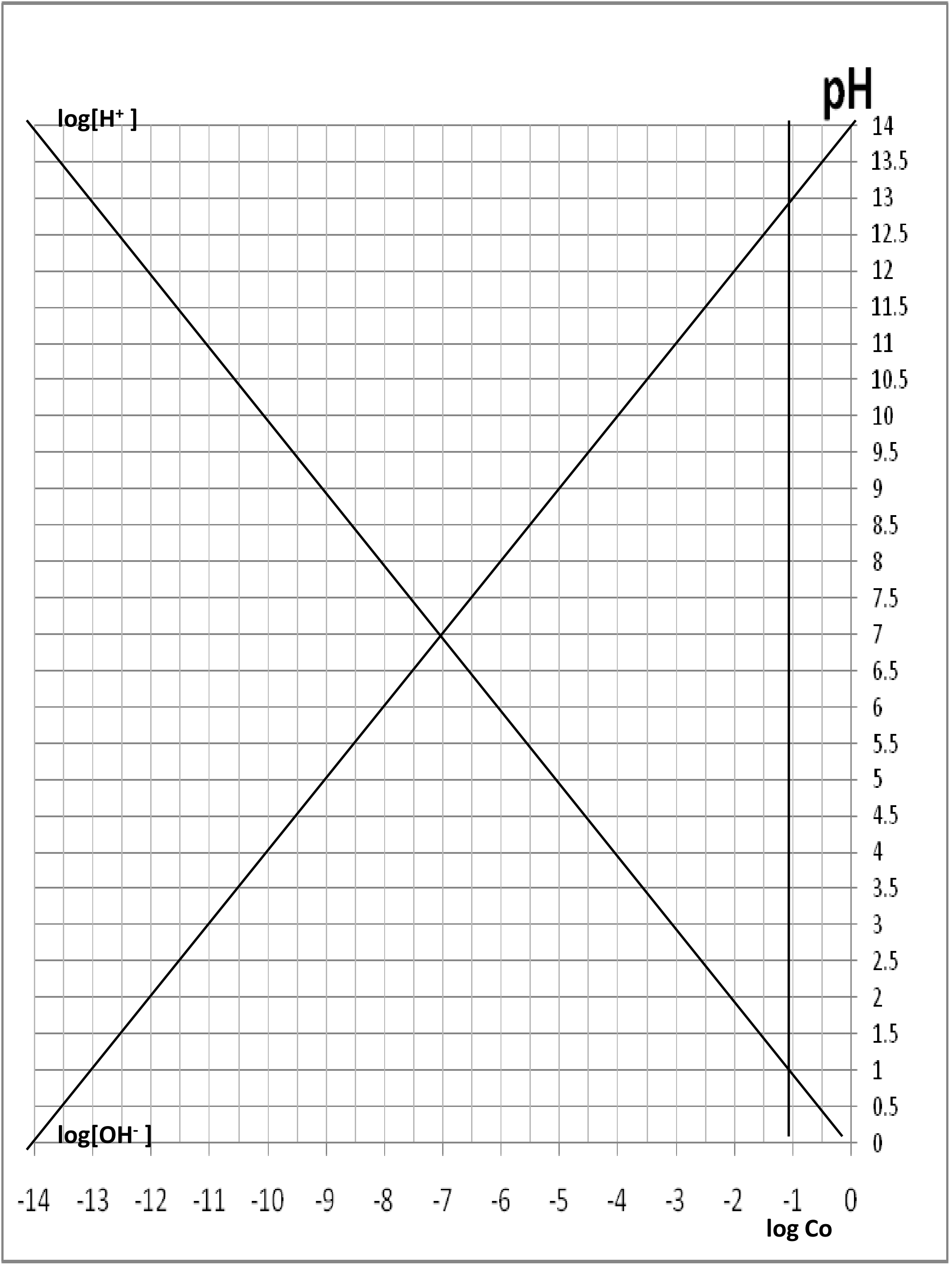
pH
log[H⁺]
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0

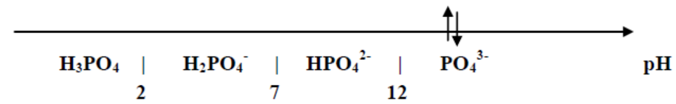


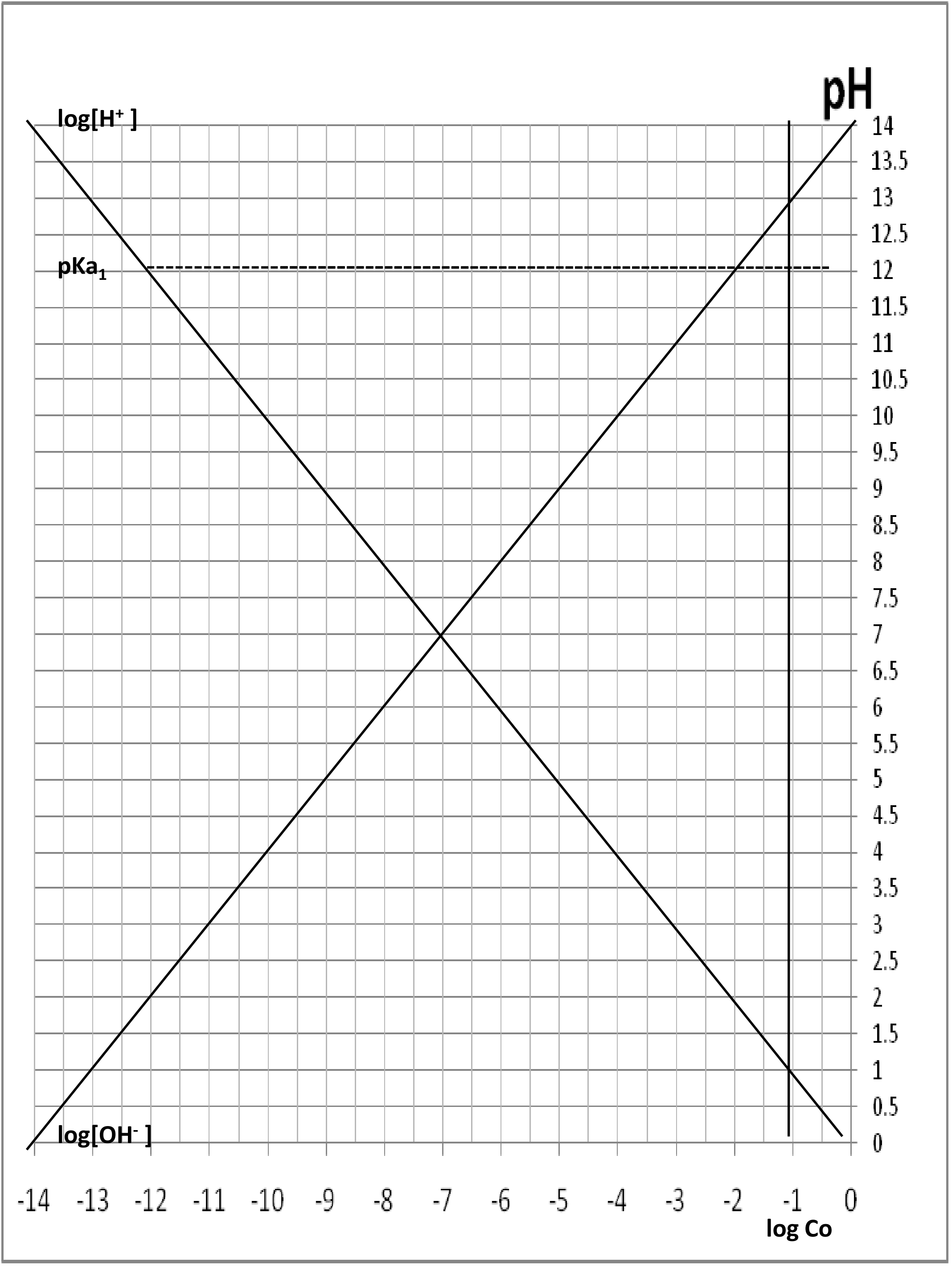
H_3PO_4
$H_2PO_4^-$
HPO_4^{2-}
PO_4^{3-}
pH
2
7
12

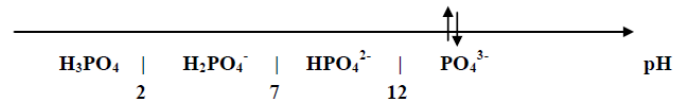

pH
log[H⁺]
log[OH⁻]
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0

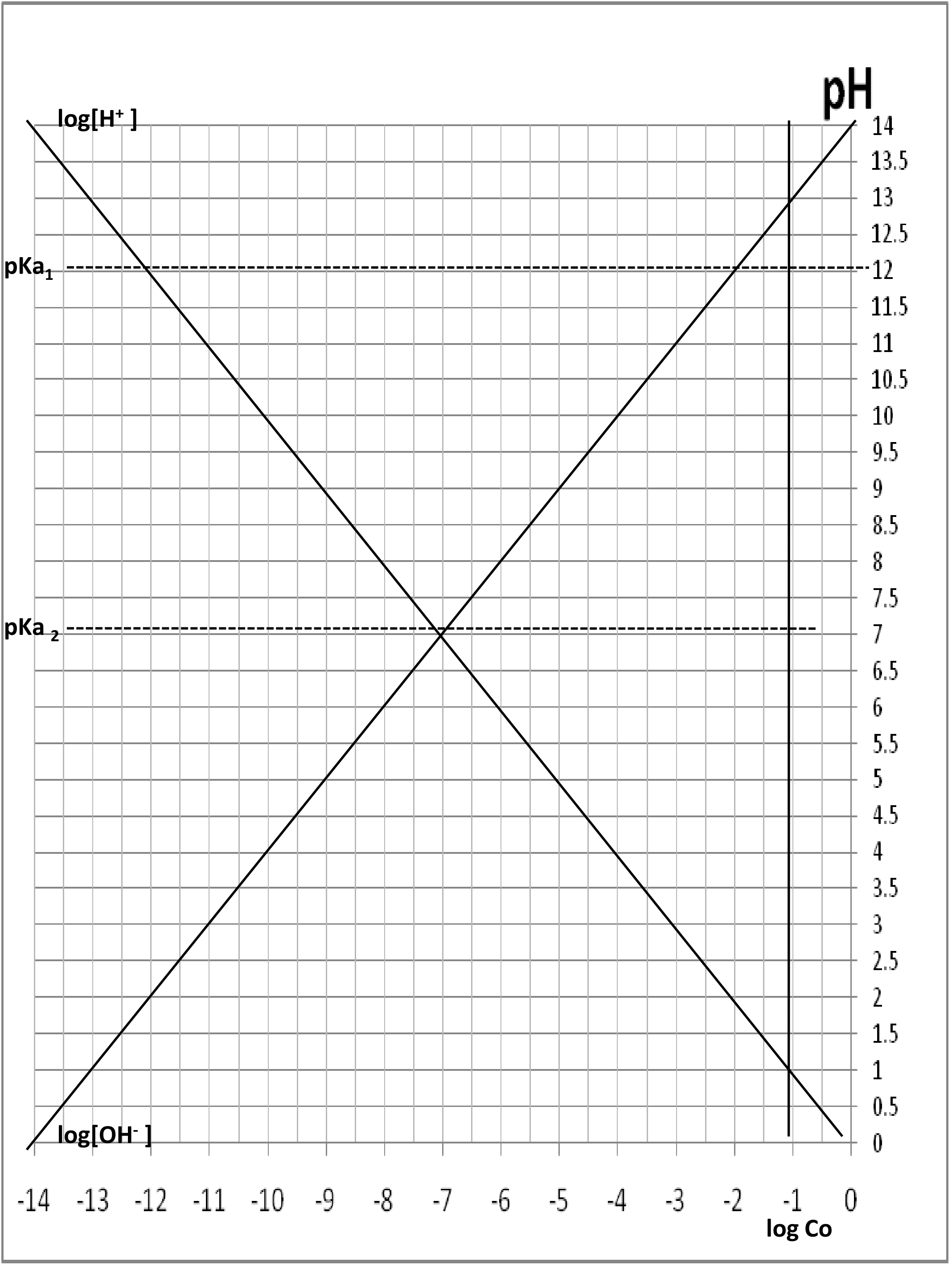

H_3PO_4
$H_2PO_4^-$
HPO_4^{2-}
PO_4^{3-}
pH
2
7
12


pH
log[H+]
log[OH-]
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
log Co

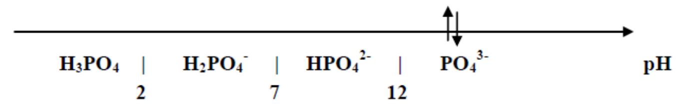

H3PO4
H2PO4-
HPO42-
PO43-
pH
2
7
12


pH
log[H+]
pKa1
log[OH-]
log Co
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0

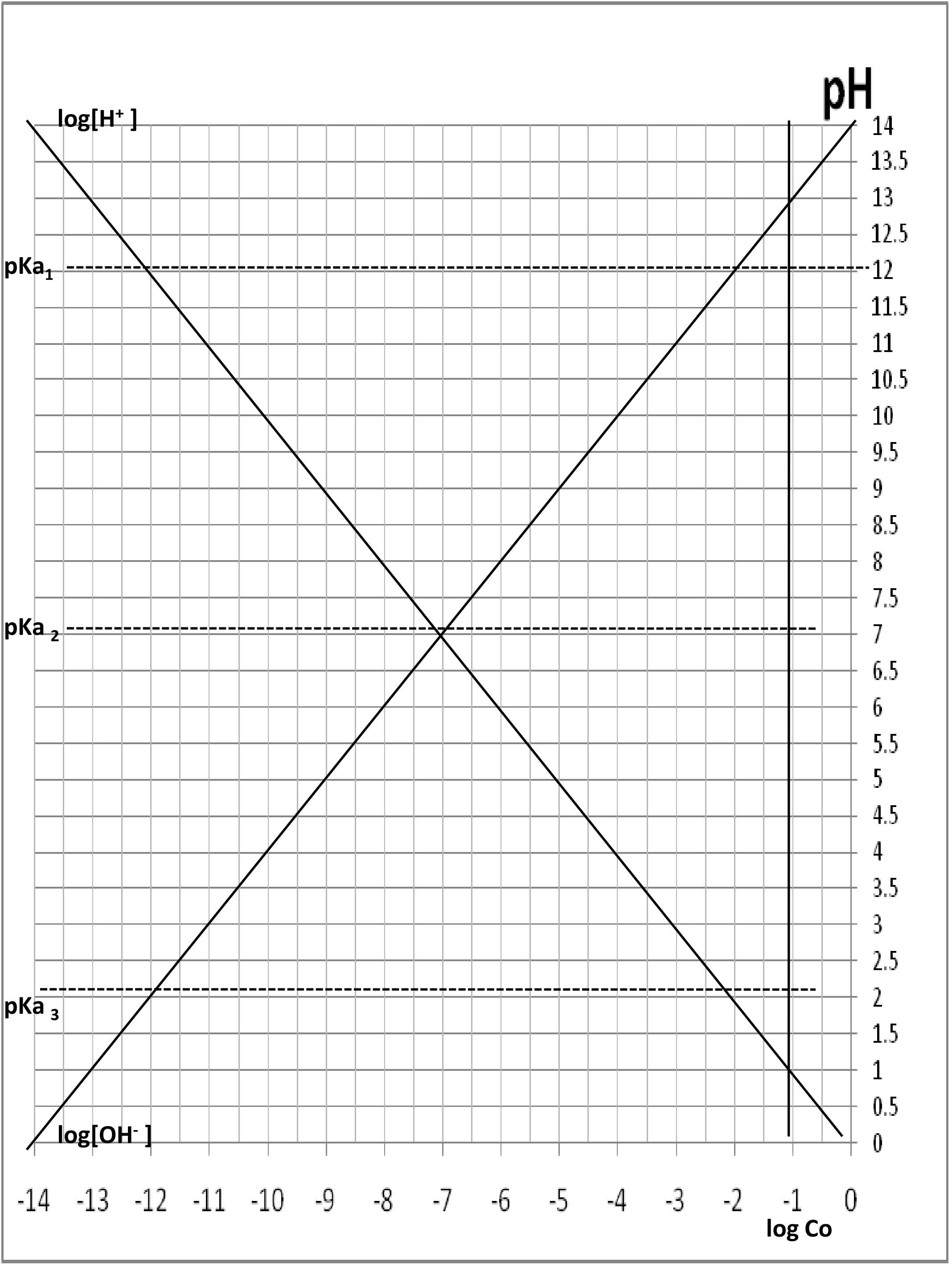

H3PO4
2
H2PO4-
7
HPO42-
12
PO43-
pH



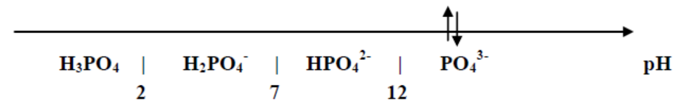
pH
log[H+]
log[OH-]
pKa1
pKa 2
log Co
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0



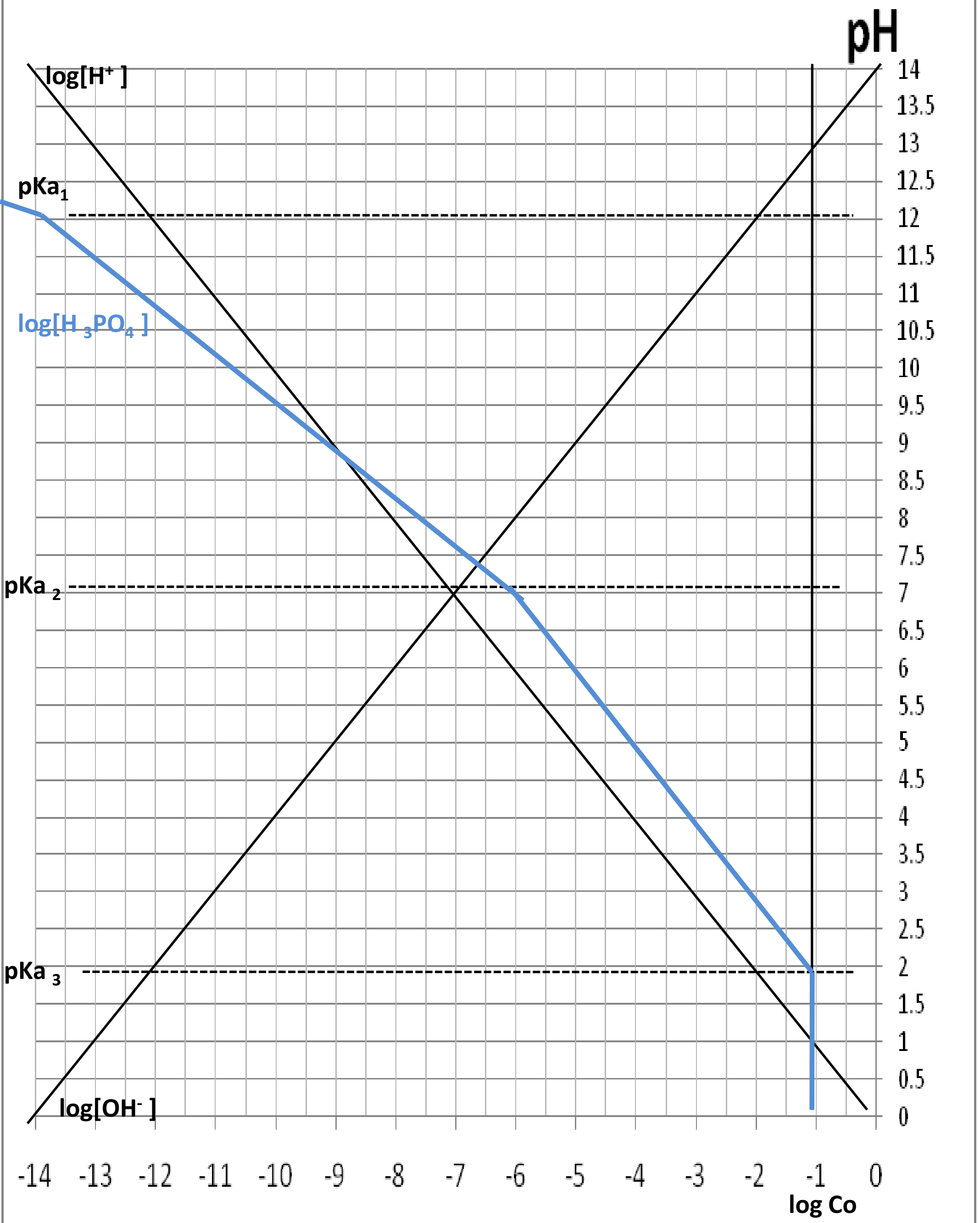
H_3PO_4
$H_2PO_4^-$
HPO_4^{2-}
PO_4^{3-}
pH
2
7
12



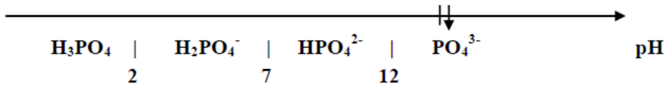
pH
log[H+]
log[OH-]
pKa1
pKa 2
pKa 3
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
log Co



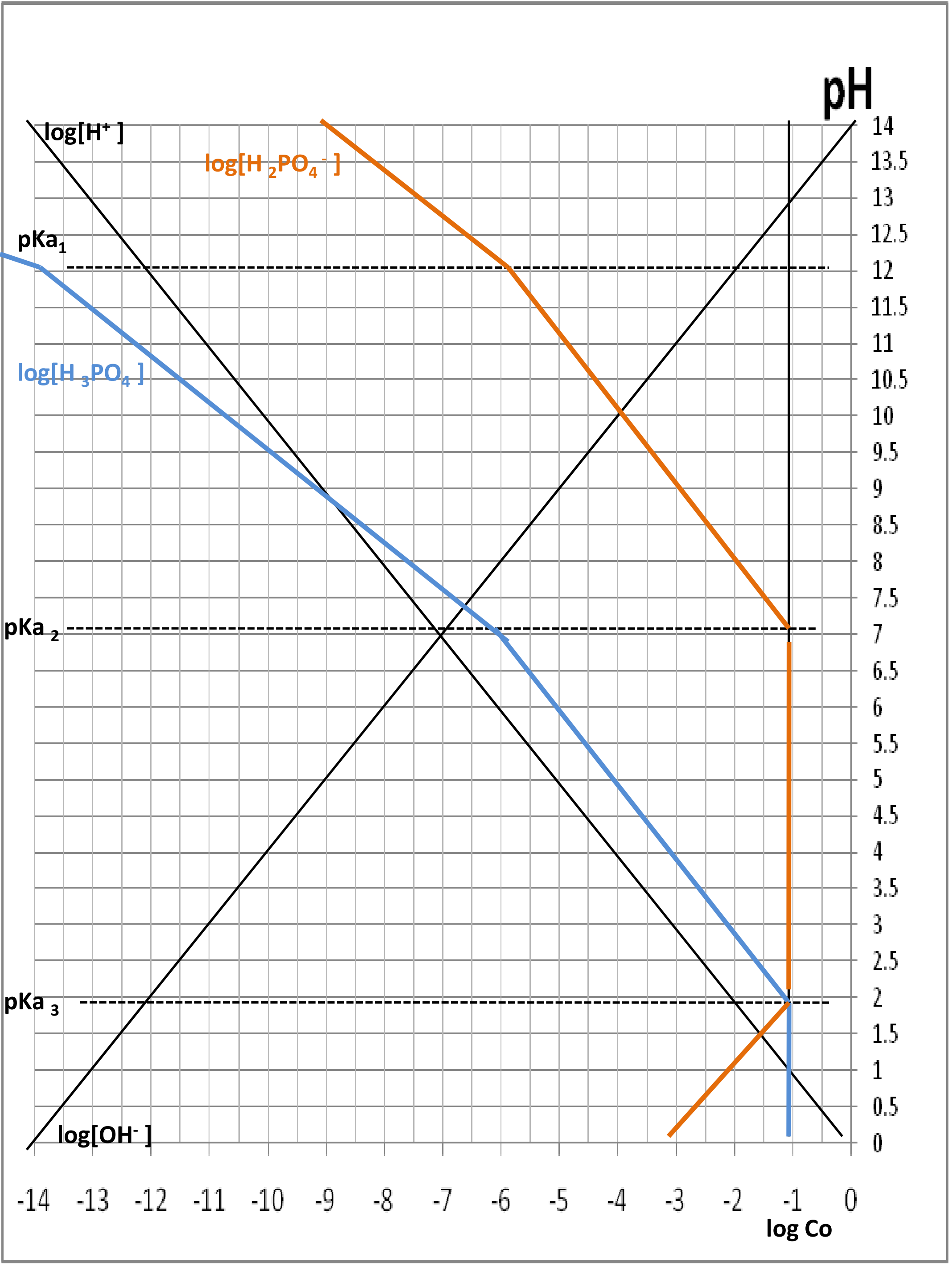
H3PO4
H2PO4-
HPO42-
PO43-
pH
2
7
12



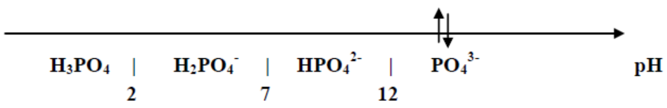
pH
log[H+]
pKa1
log[H3PO4]
pKa 2
pKa 3
log[OH-]
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
log Co



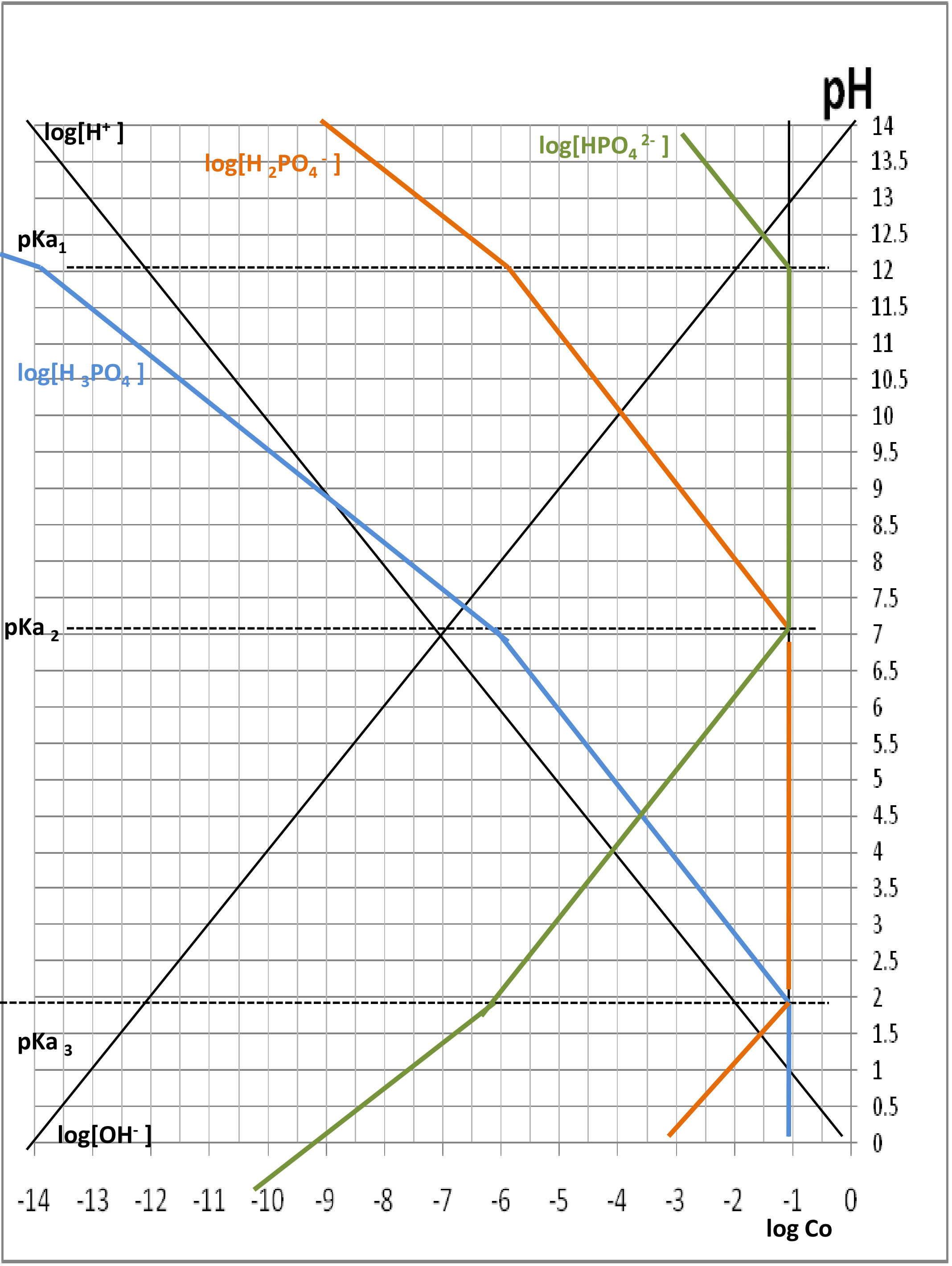
H3PO4
2
H2PO4-
7
HPO42-
12
PO43-
pH



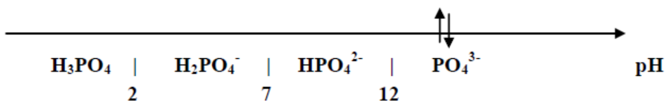
pH
log[H+]
log[H 2PO4 -]
pKa1
log[H 3PO4]
pKa 2
pKa 3
log[OH-]
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
log Co



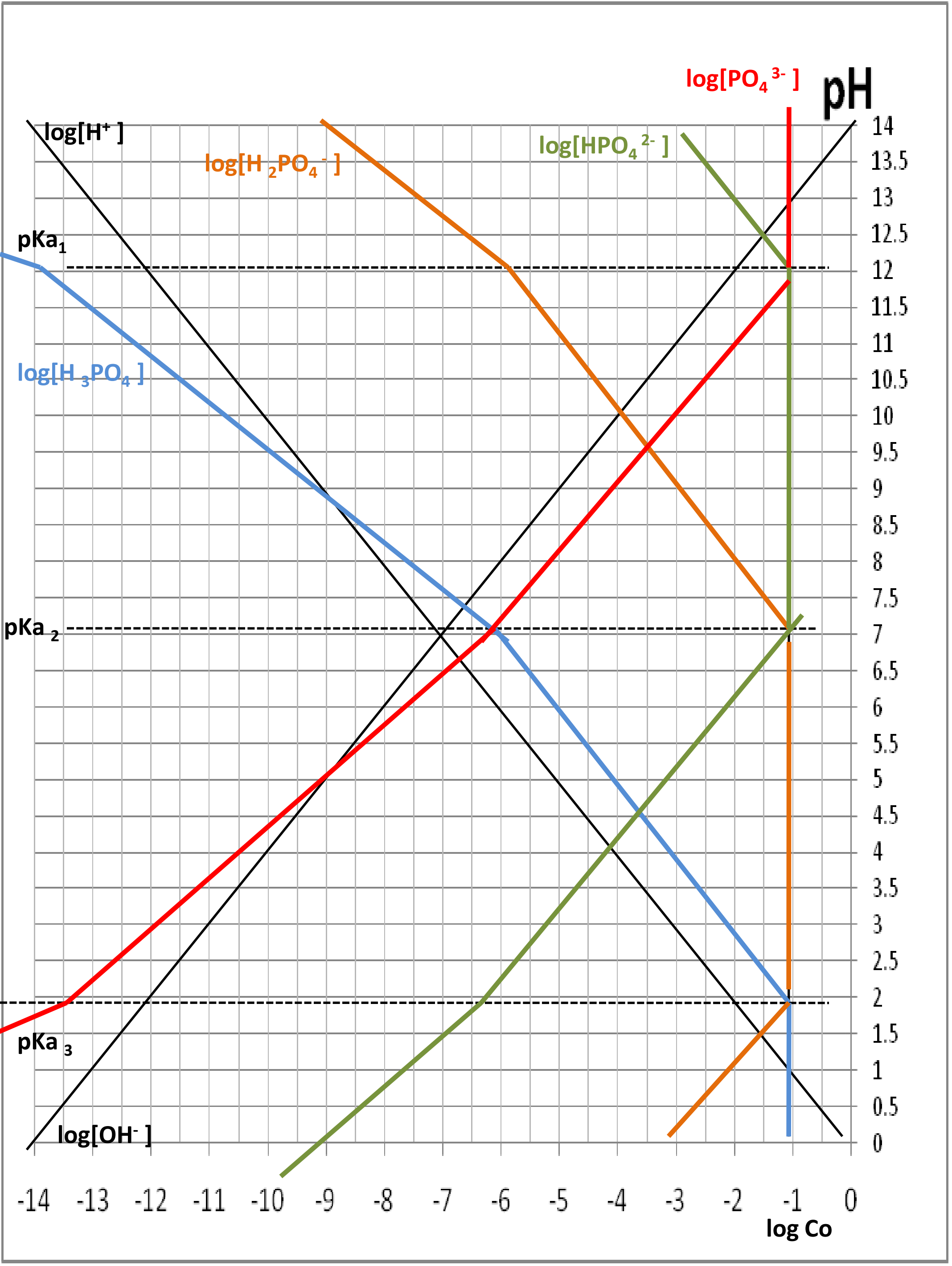
H3PO4 | H2PO4- | HPO42- | PO43-
2 7 12
pH



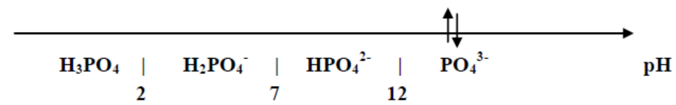
pH
log[H⁺]
log[$H_2PO_4^-$]
log[HPO_4^{2-}]
pKa1
log[H_3PO_4]
pKa 2
pKa 3
log[OH⁻]
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
log Co



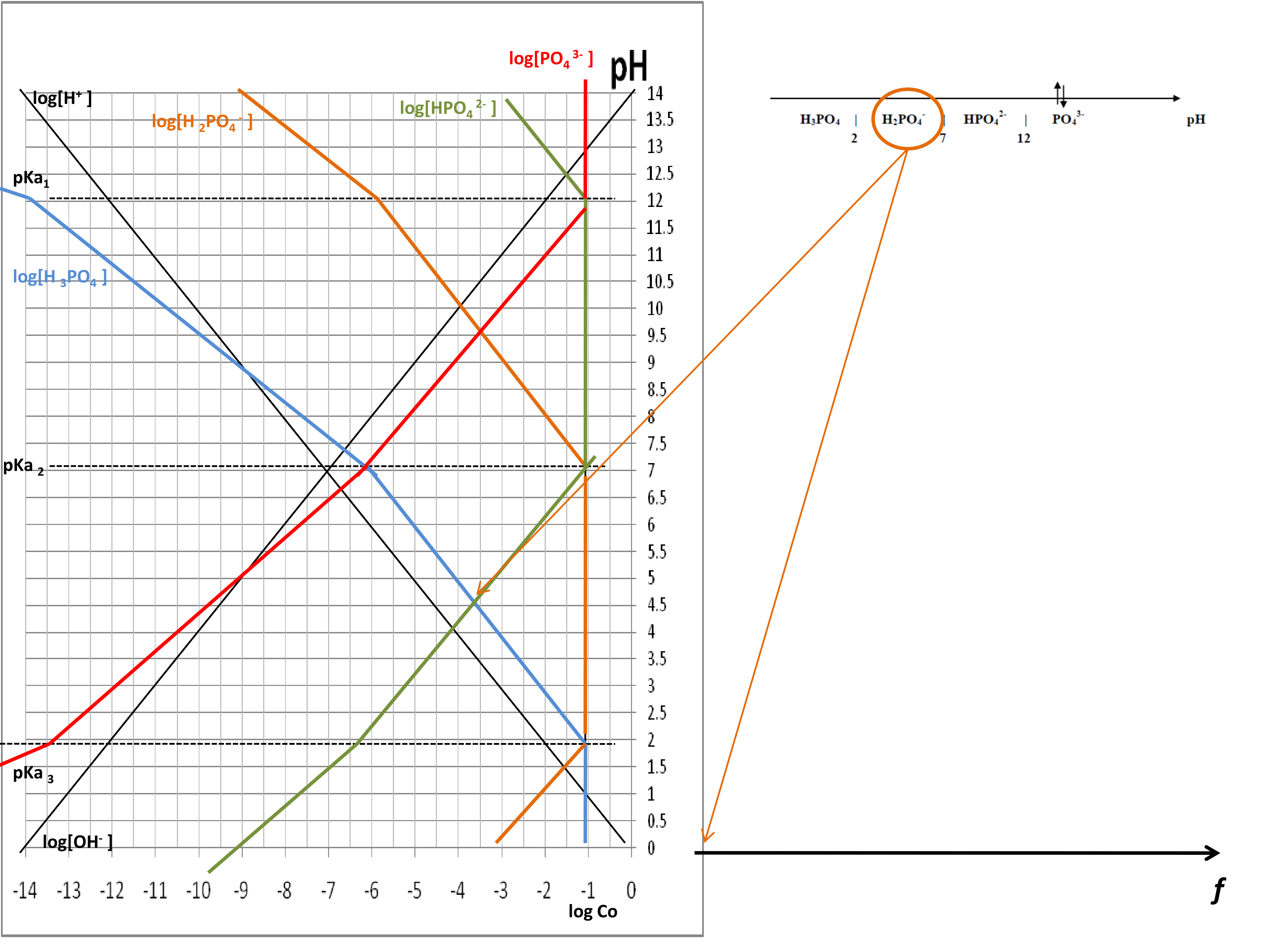
H_3PO_4
$H_2PO_4^-$
HPO_4^{2-}
PO_4^{3-}
pH
2
7
12



pH
log[PO4 3-]
log[H+]
log[H 2PO4 -]
log[HPO4 2-]
pKa1
log[H 3PO4]
pKa 2
pKa 3
log[OH-]
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
log Co



H3PO4
2
H2PO4-
7
HPO4 2-
12
PO4 3-
pH



log[PO4 3-]
pH
log[H+]
log[H 2PO4 -]
log[HPO4 2-]
pKa1
log[H 3PO4]
pKa 2
pKa 3
log[OH-]
log Co
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
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1
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-14
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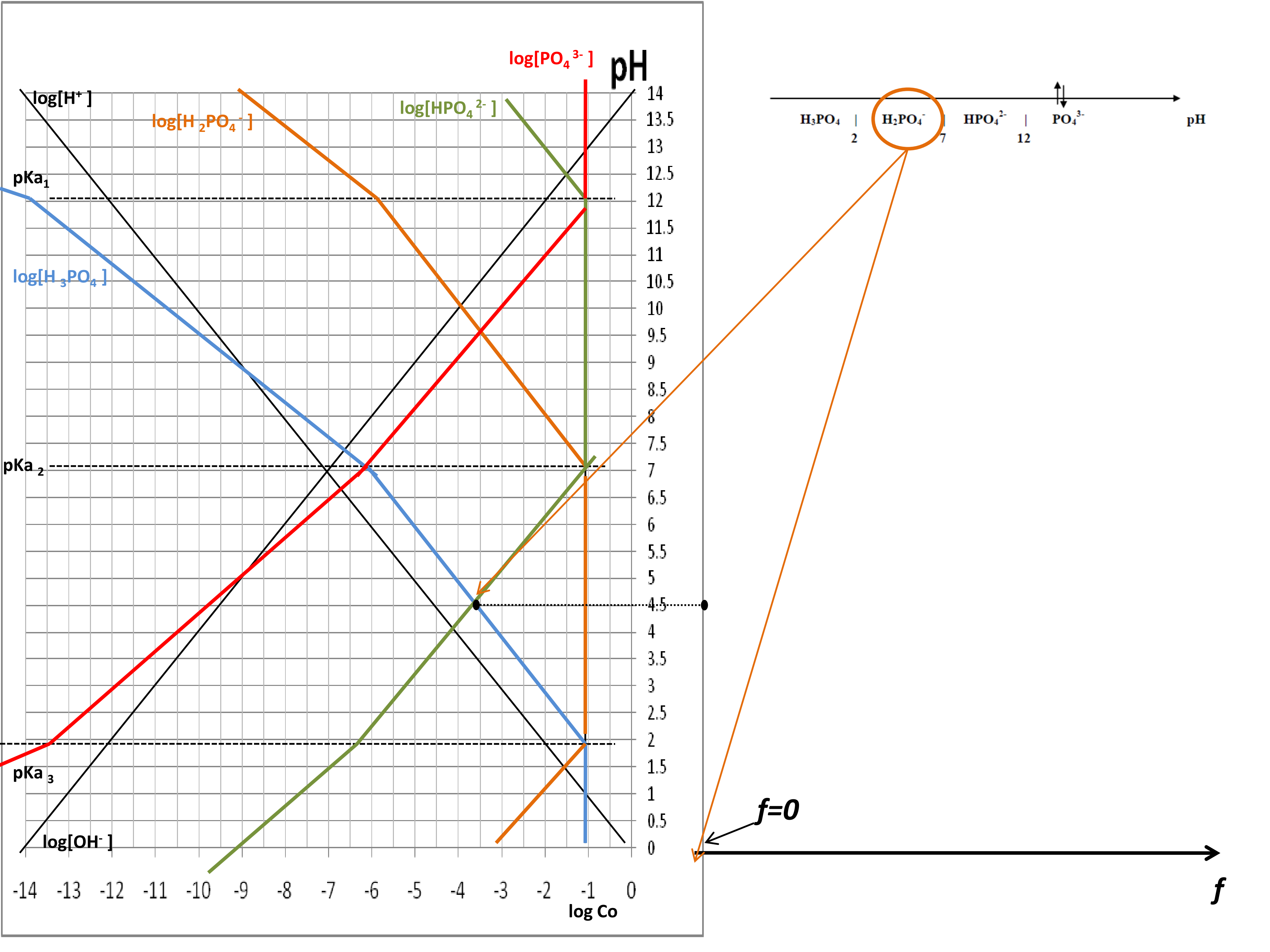
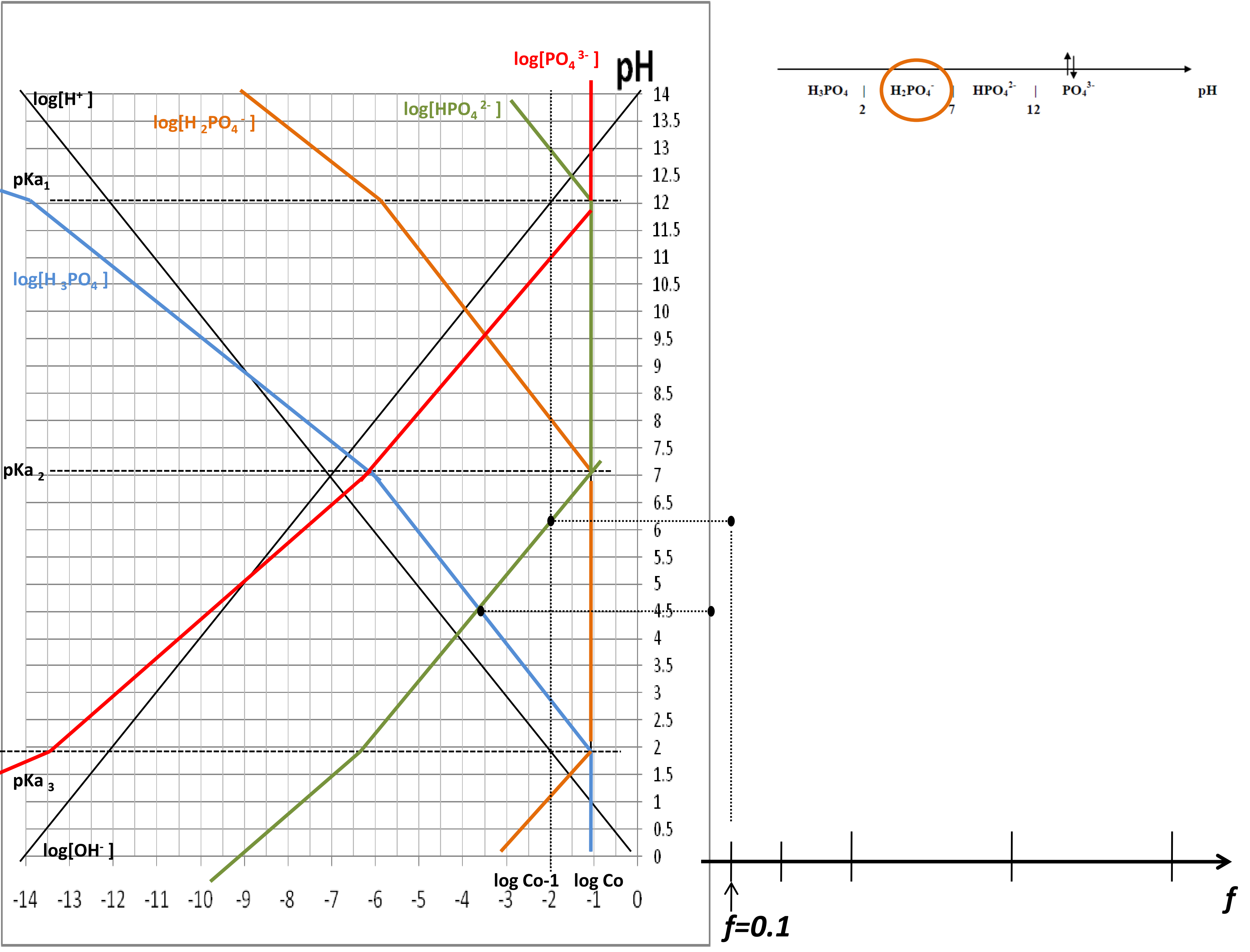
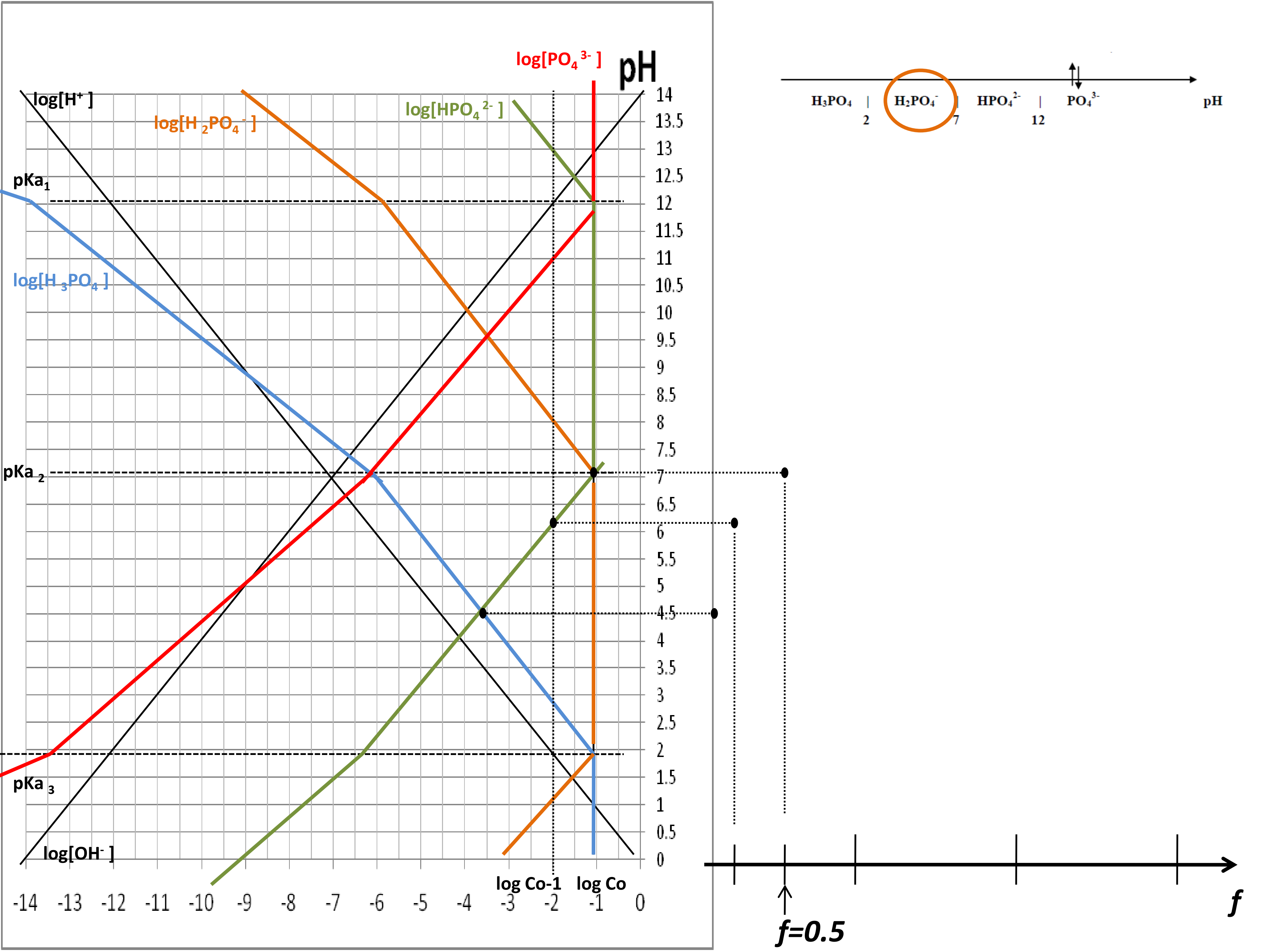
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
H3PO4
H2PO4-
HPO4 2-
PO4 3-
pH
2
7
12
f



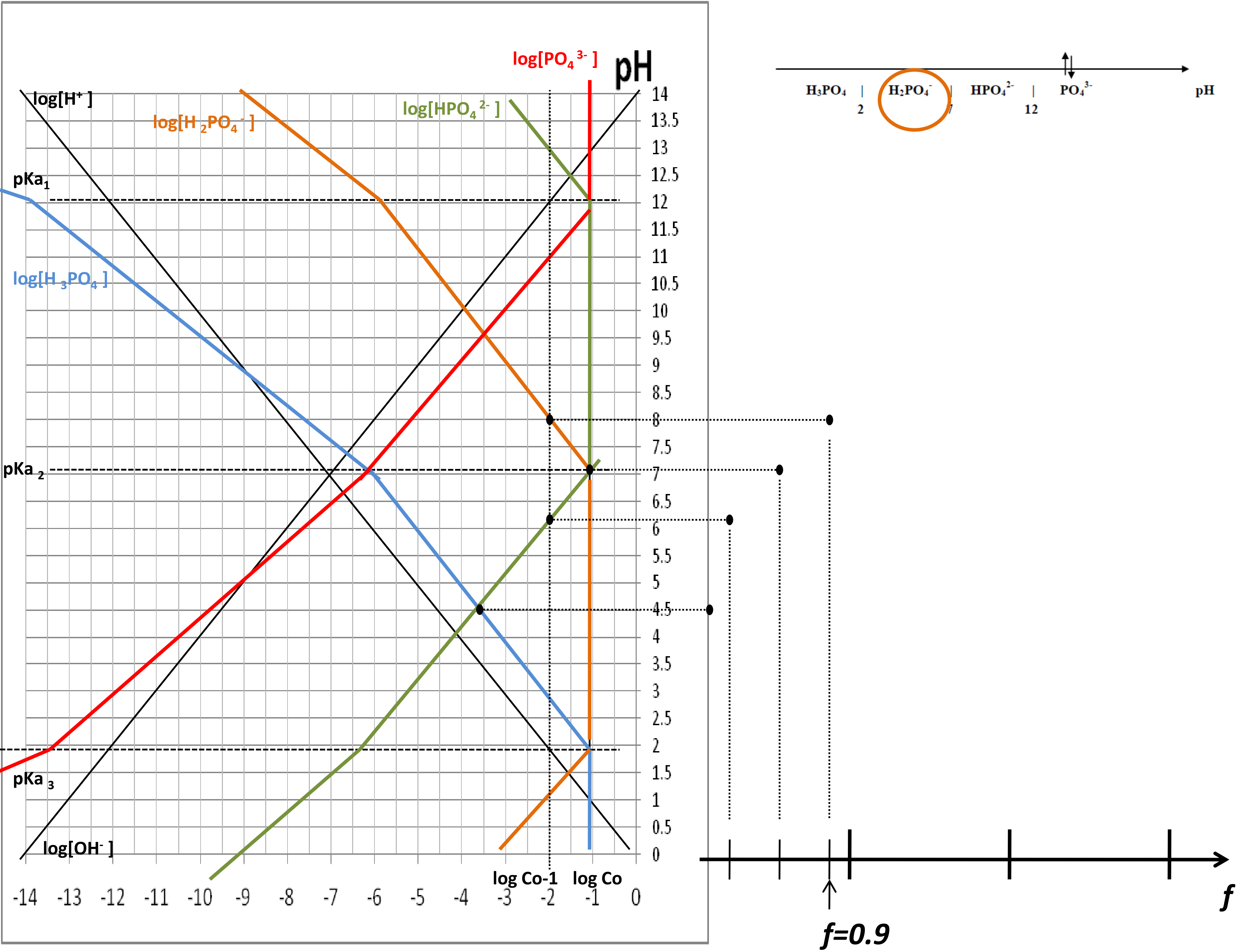
log[PO4 3-]
pH
log[H+]
log[H 2PO4 -]
log[HPO4 2-]
pKa1
log[H 3PO4]
pKa 2
pKa 3
log[OH-]
log Co
H3PO4
H2PO4-
HPO42-
PO43-
pH
2
7
12
f=0
f



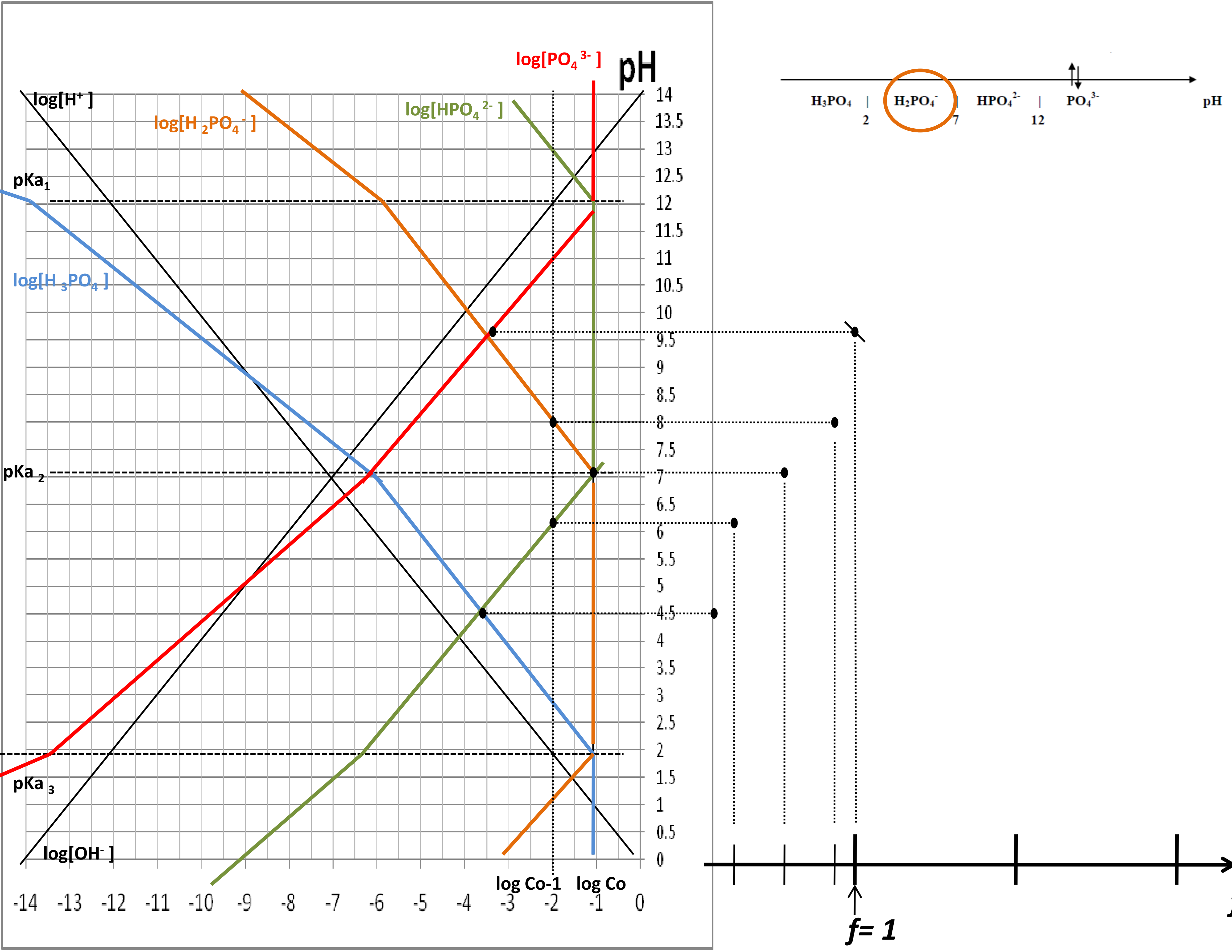
pH
log[H+]
log[$H_2PO_4^-$]
log[HPO_4^{2-}]
log[PO_4^{3-}]
log[H_3PO_4]
pKa1
pKa 2
pKa 3
log[OH-]
log Co-1
log Co
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
H_3PO_4
2
$H_2PO_4^-$
7
HPO_4^{2-}
12
PO_4^{3-}
pH
f
f=0.1



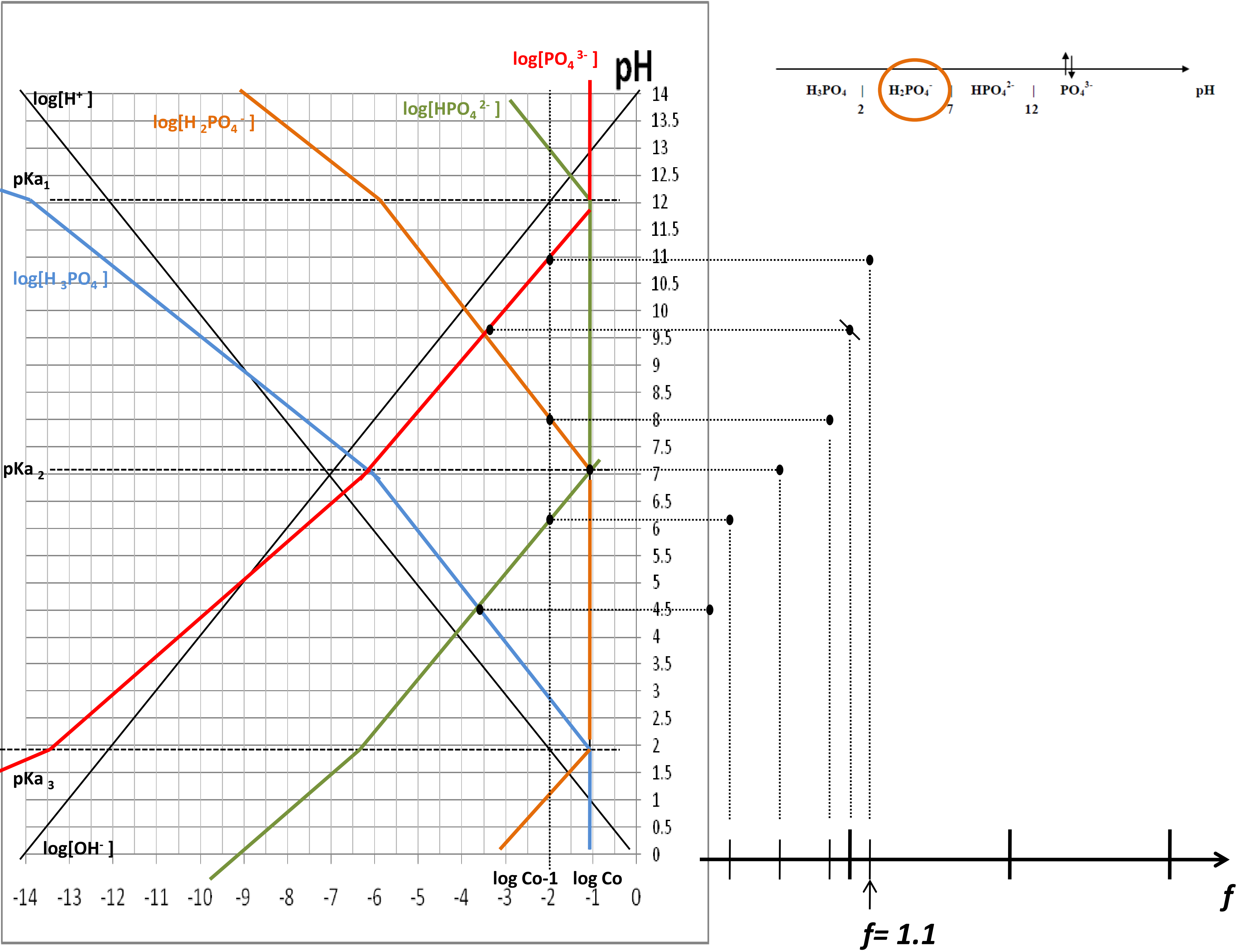
log[PO4 3-]
pH
log[H+]
log[H 2PO4 -]
log[HPO4 2-]
pKa1
log[H 3PO4]
pKa 2
pKa 3
log[OH-]
log Co-1
log Co
14 13.5 13 12.5 12 11.5 11 10.5 10 9.5 9 8.5 8 7.5 7 6.5 6 5.5 5 4.5 4 3.5 3 2.5 2 1.5 1 0.5 0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
H3PO4
H2PO4-
HPO4 2-
PO4 3-
pH
2
7
12
f
f=0.5



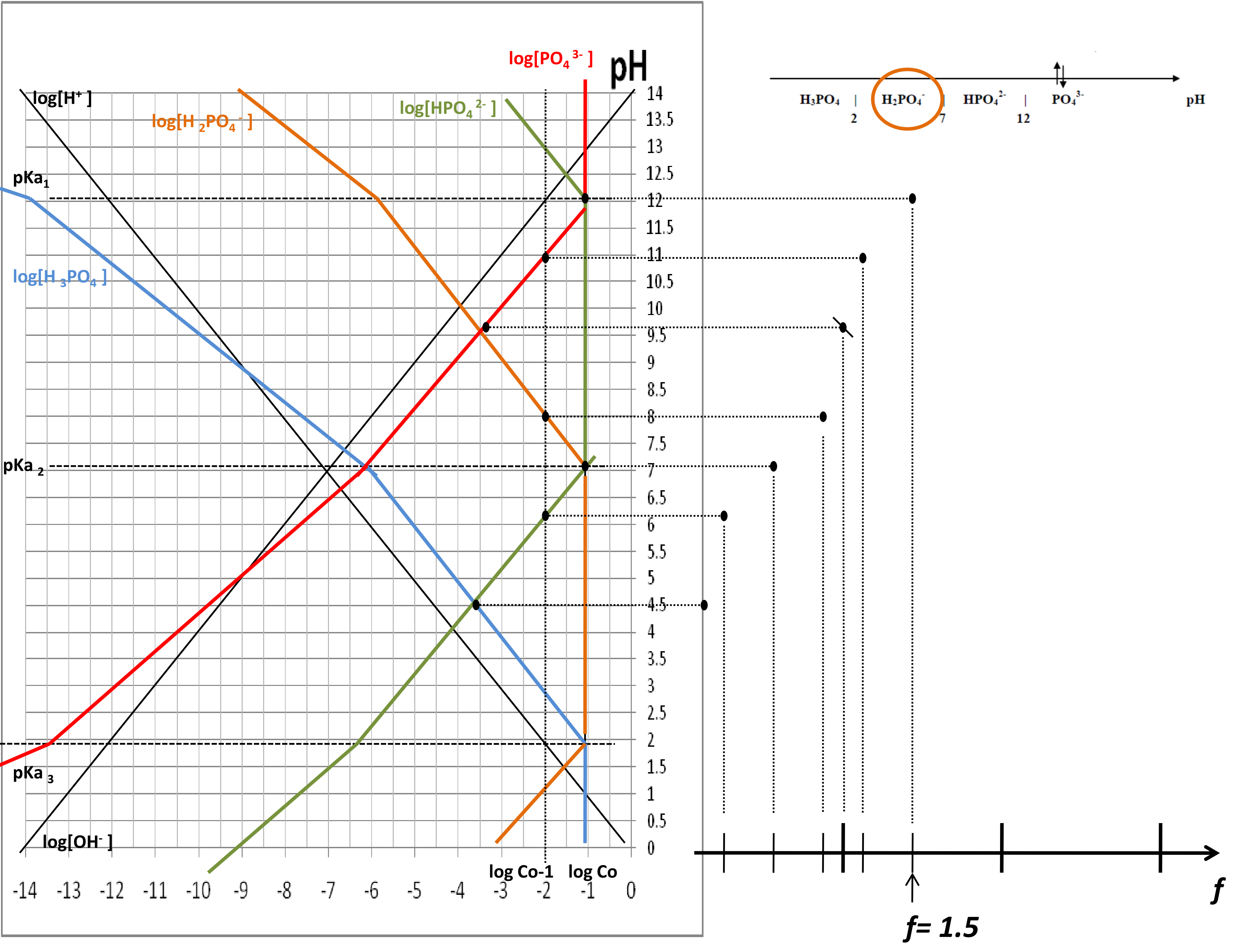
log[H+]
log[H 2PO4-]
log[HPO4 2-]
log[PO4 3-]
pH
pKa1
log[H 3PO4]
pKa 2
pKa 3
log[OH-]
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
log Co-1
log Co
H3PO4 | H2PO4- | HPO42- | PO43-
2
12
pH
f
f=0.9



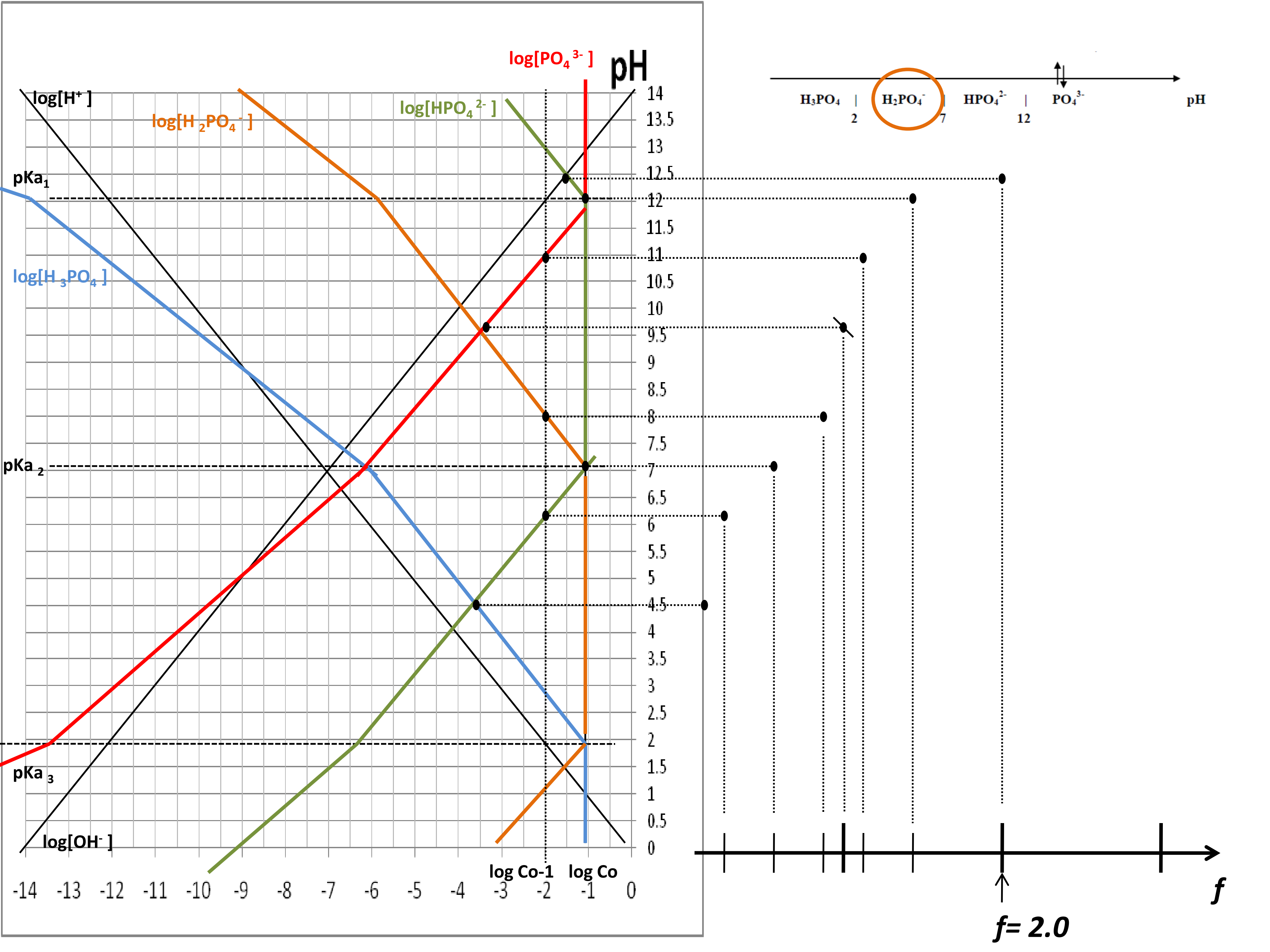
pH
log[PO4 3-]
log[H+]
log[H 2PO4 -]
log[HPO4 2-]
log[H 3PO4]
log[OH-]
pKa1
pKa 2
pKa 3
log Co-1
log Co
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
H3PO4
2
H2PO4-
7
HPO4 2-
12
PO4 3-
pH
f
f= 1



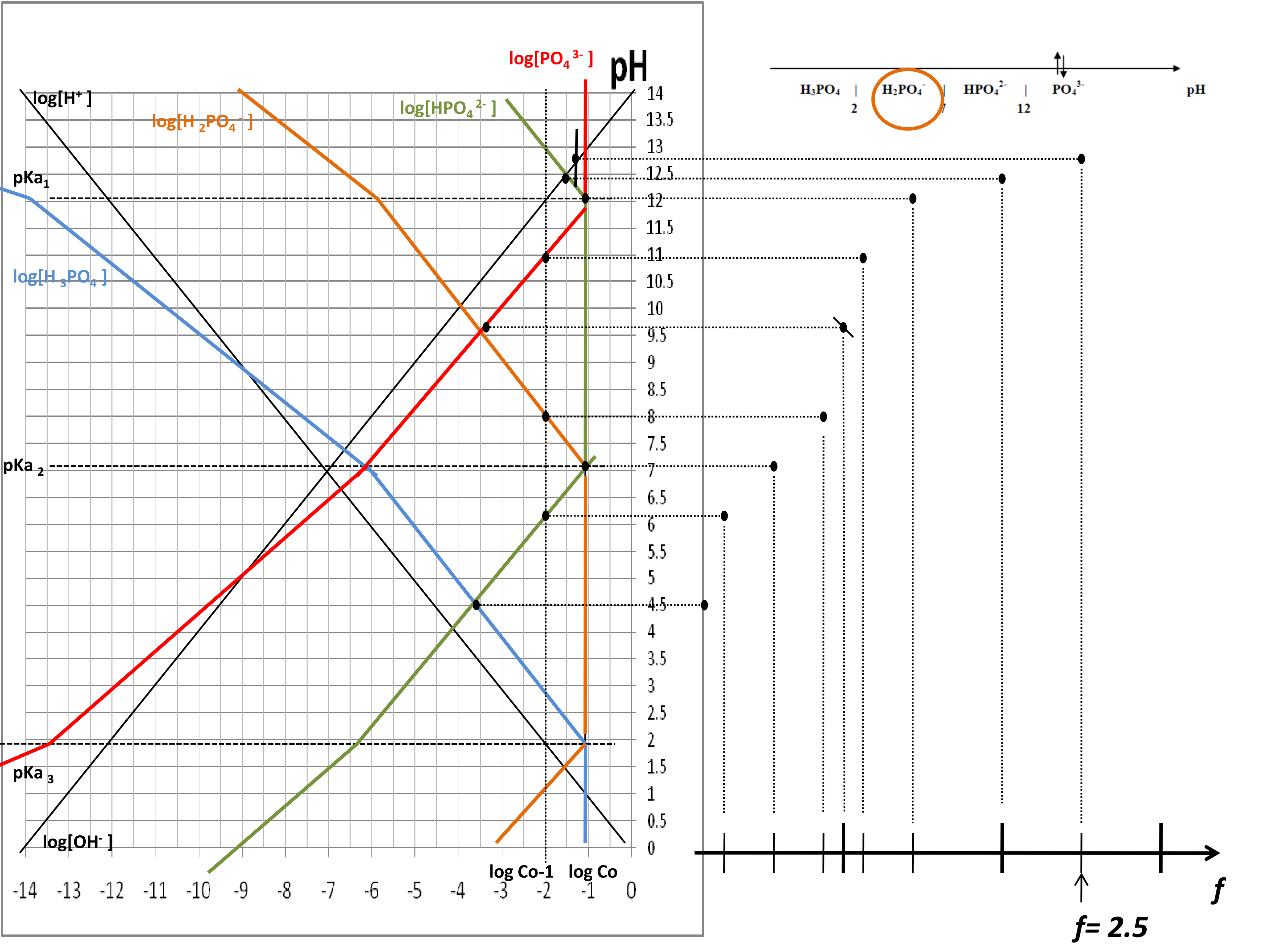
log[H+]
log[H 2PO4-]
log[HPO4 2-]
log[PO4 3-]
pH
log[H 3PO4]
log[OH-]
pKa1
pKa 2
pKa 3
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
log Co-1
log Co
H3PO4 | H2PO4- | HPO4 2- | PO4 3-
2
7
12
pH
f
f= 1.1



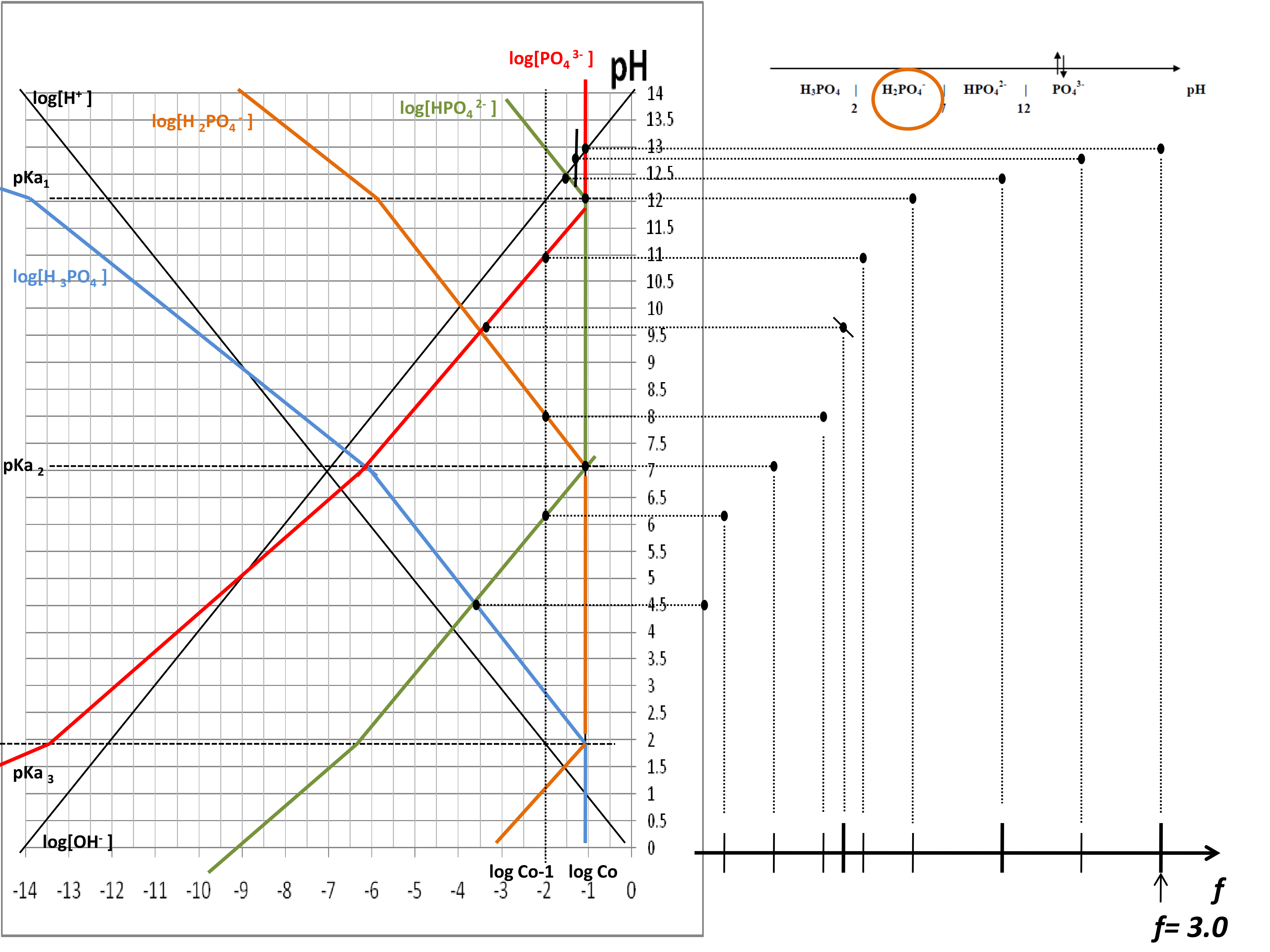
log[PO4 3-]
pH
log[H+]
log[H 2PO4 -]
log[HPO4 2-]
pKa1
log[H 3PO4]
pKa 2
pKa 3
log[OH-]
log Co-1
log Co
H3PO4
H2PO4-
HPO4 2-
PO4 3-
pH
2
7
12
f
f= 1.5

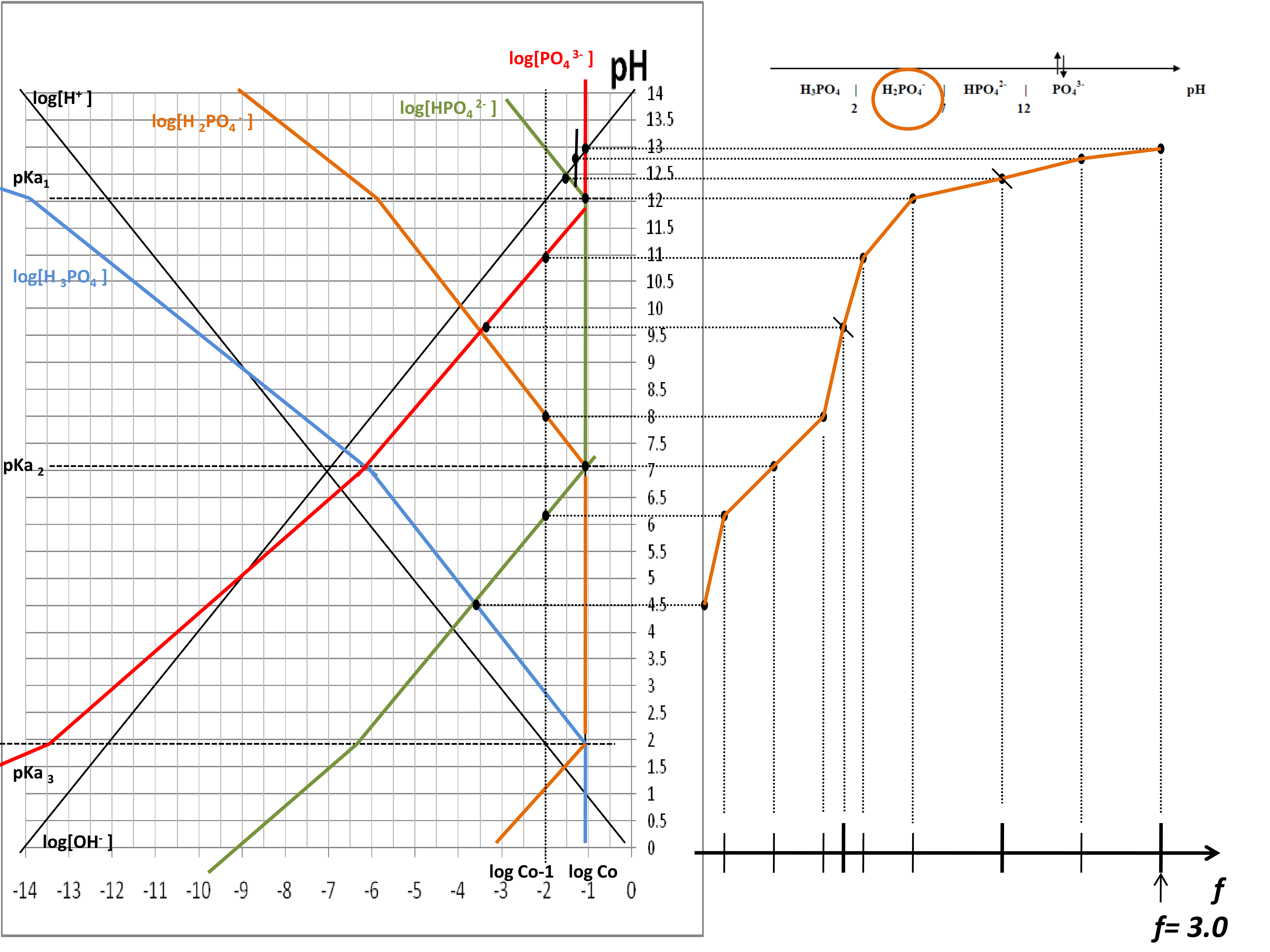


log[PO4 3-]
pH
log[H+]
log[H 2PO4 -]
log[HPO4 2-]
pKa1
log[H 3PO4]
pKa 2
pKa 3
log[OH-]
log Co-1
log Co
H3PO4
H2PO4-
HPO4 2-
PO4 3-
pH
2
7
12
f
f= 2.0

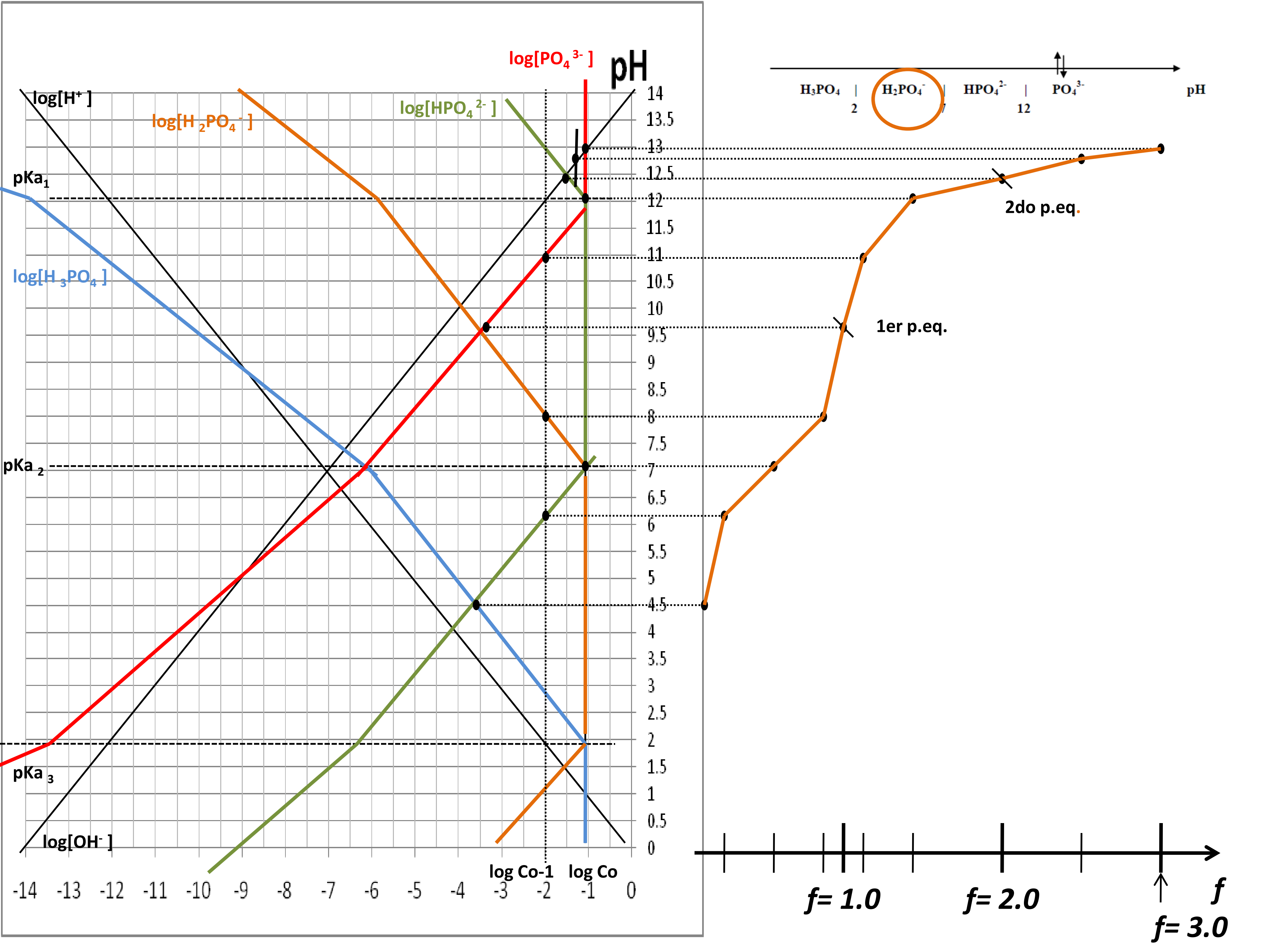


log[PO4 3-]
pH
log[H+]
log[H 2PO4-]
log[HPO4 2-]
pKa1
log[H 3PO4]
pKa 2
pKa 3
log[OH-]
log Co-1
log Co
H3PO4 | 2 H2PO4- | 7 HPO4 2- | 12 PO4 3-
pH
f
f= 2.5

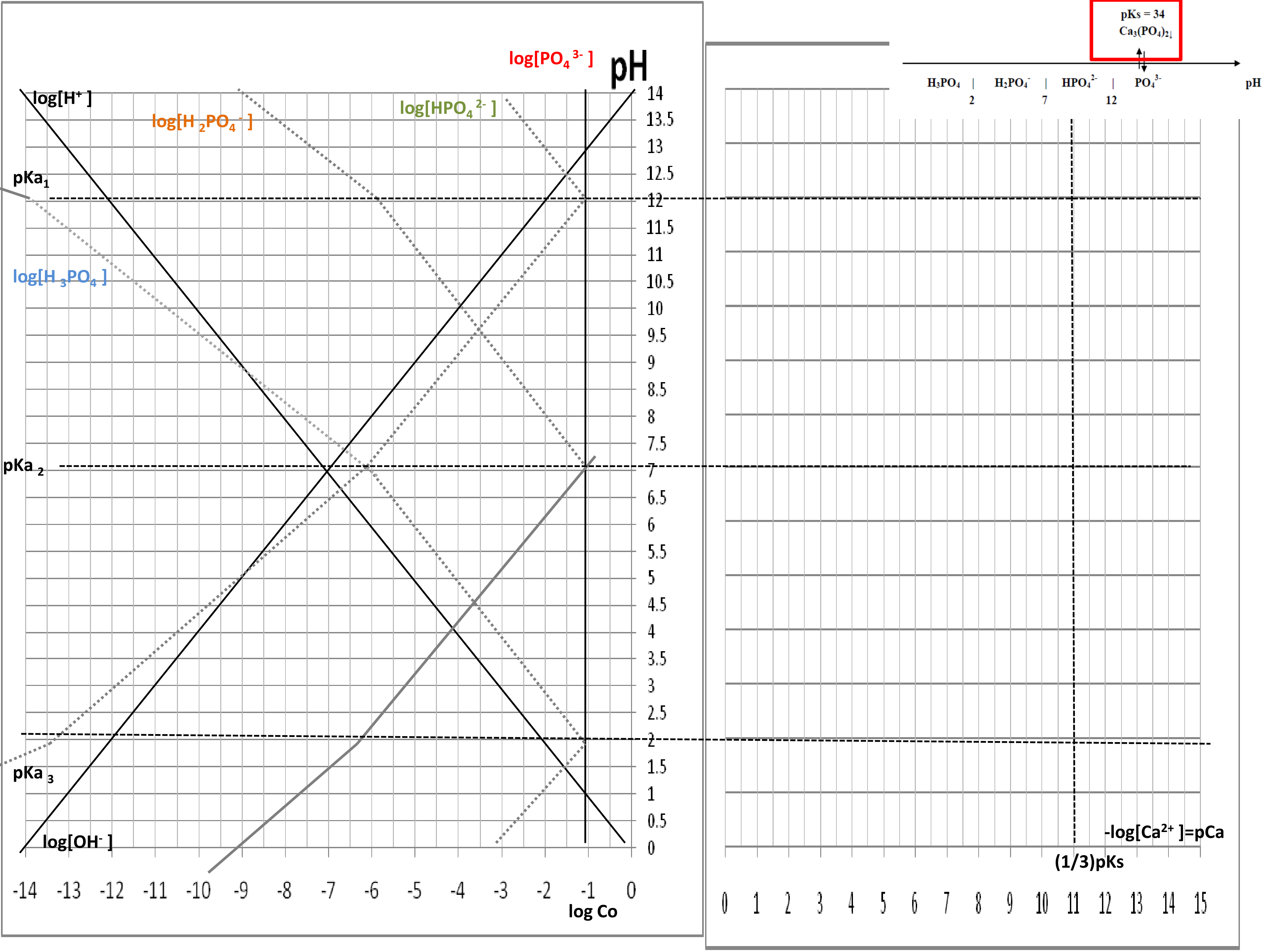

log[PO4 3-]
pH
log[H+]
log[H 2PO4 -]
log[HPO4 2-]
pKa1
log[H 3PO4]
pKa 2
pKa 3
log[OH-]
log Co-1
log Co
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
H3PO4 | H2PO4- | HPO4 2- | PO4 3- pH
2
7
12
f
f= 3.0



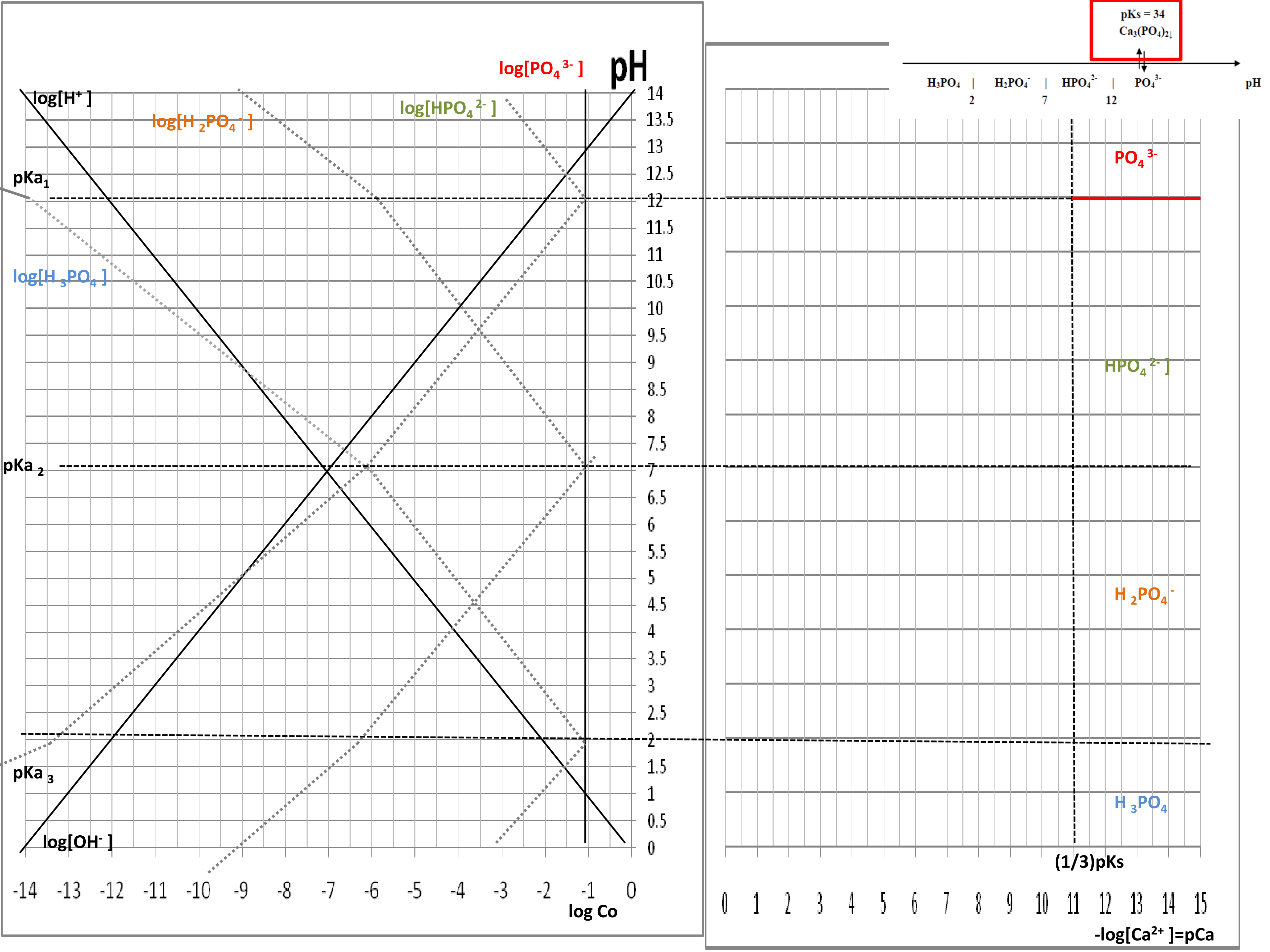
log[PO4 3-]
pH
log[H+]
log[H 2PO4 -]
log[HPO4 2-]
log[H 3PO4]
log[OH-]
pKa1
pKa 2
pKa 3
log Co-1
log Co
H3PO4
H2PO4-
HPO4 2-
PO4 3-
2
12
pH
f
f= 3.0

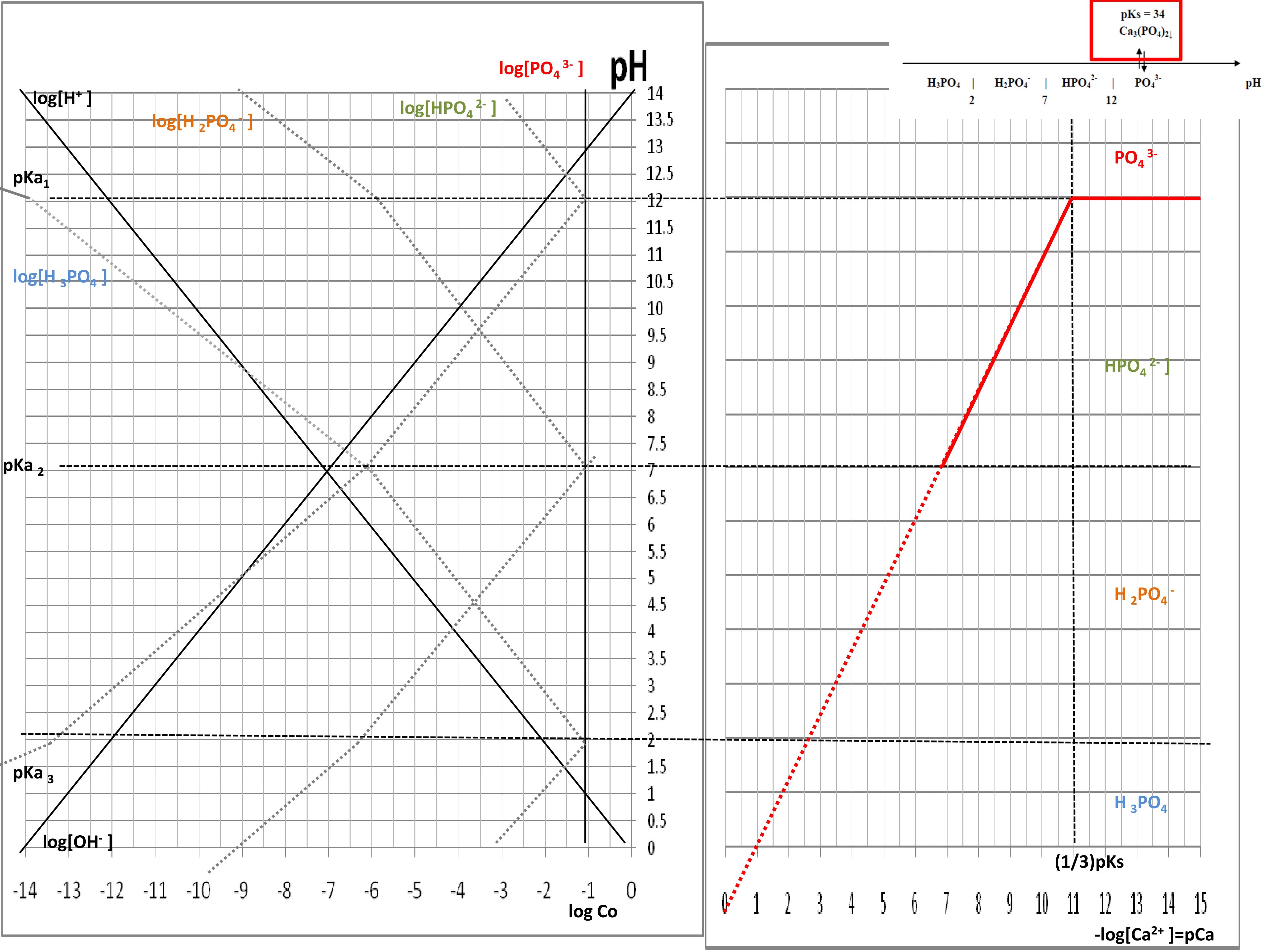


log[PO4 3-]
pH
log[H+]
log[H 2PO4 -]
log[HPO4 2-]
pKa1
pKa 2
pKa 3
log[H 3PO4]
log[OH-]
log Co-1
log Co
H3PO4 | 2 H2PO4- | 7 HPO4 2- | 12 PO4 3- pH
2do p.eq.
1er p.eq.
f= 1.0
f= 2.0
f= 3.0
f

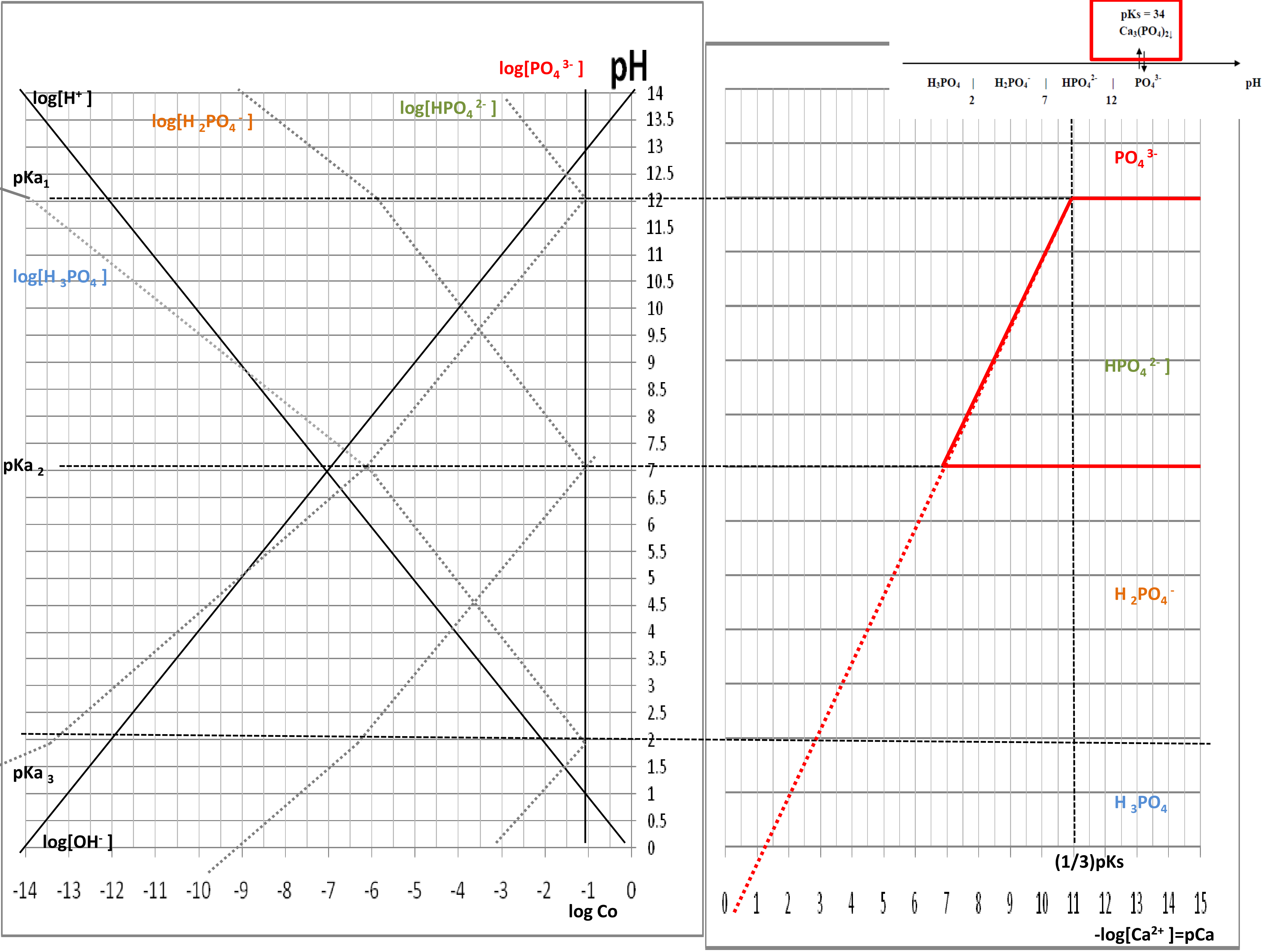


log[PO4 3-]
pH
log[H+]
log[H 2PO4 -]
log[HPO4 2-]
pKa1
log[H 3PO4]
pKa 2
pKa 3
log[OH-]
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
log Co
pKs = 34
Ca3(PO4)2↓
H3PO4 | H2PO4- | HPO42- | PO43-
pH
2
7
12
-log[Ca2+]=pCa
(1/3)pKs
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

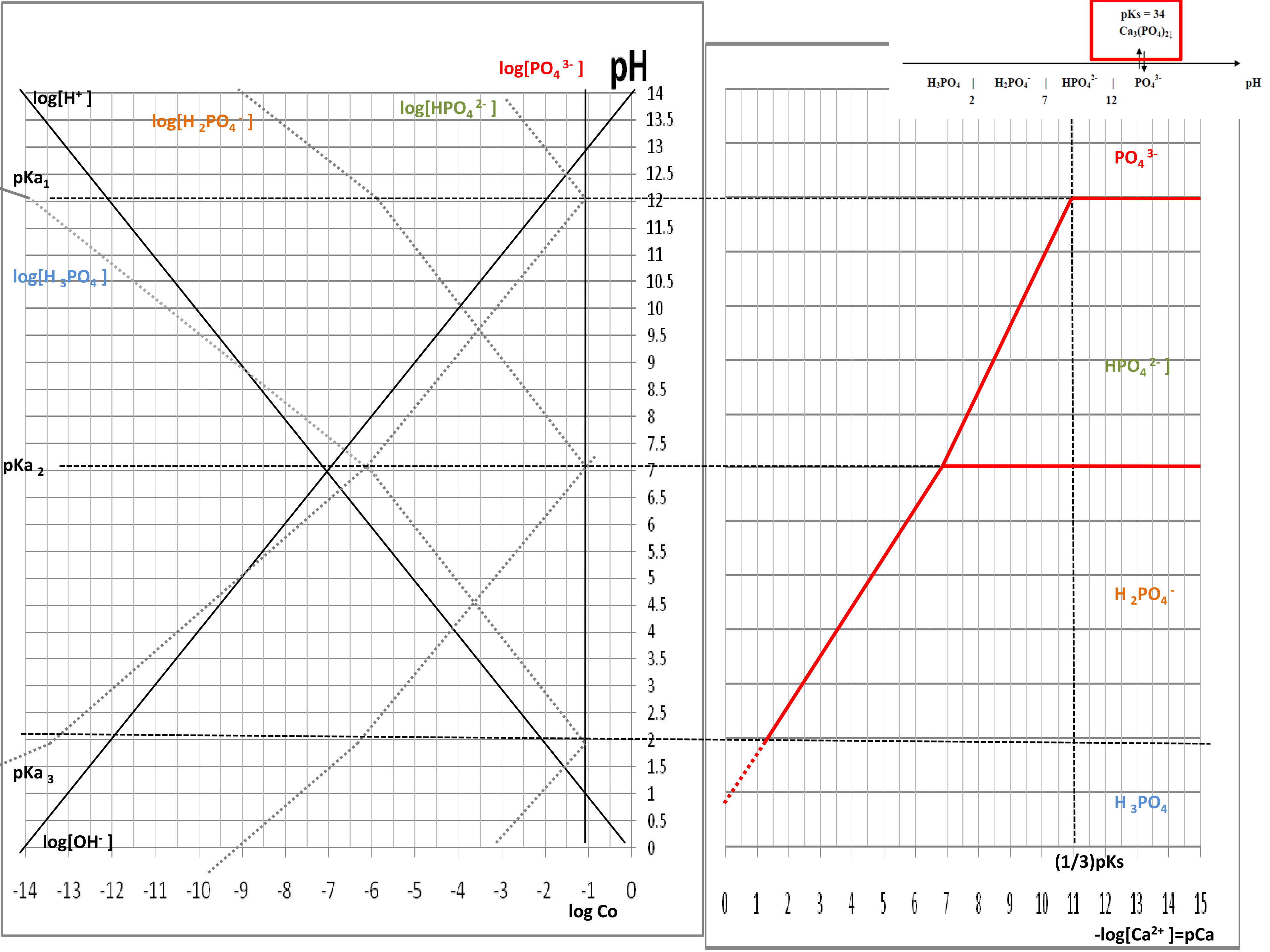

pKs = 34
Ca3(PO4)2↓
H3PO4
H2PO4-
HPO42-
PO43-
pH
2
7
12
log[PO4 3-]
pH
log[H+]
log[H 2PO4 -]
log[HPO4 2-]
pKa1
pKa 2
pKa 3
log[H 3PO4]
log[OH-]
log Co
PO4 3-
HPO4 2-]
H 2PO4 -
H 3PO4
(1/3)pKs
-log[Ca2+]=pCa



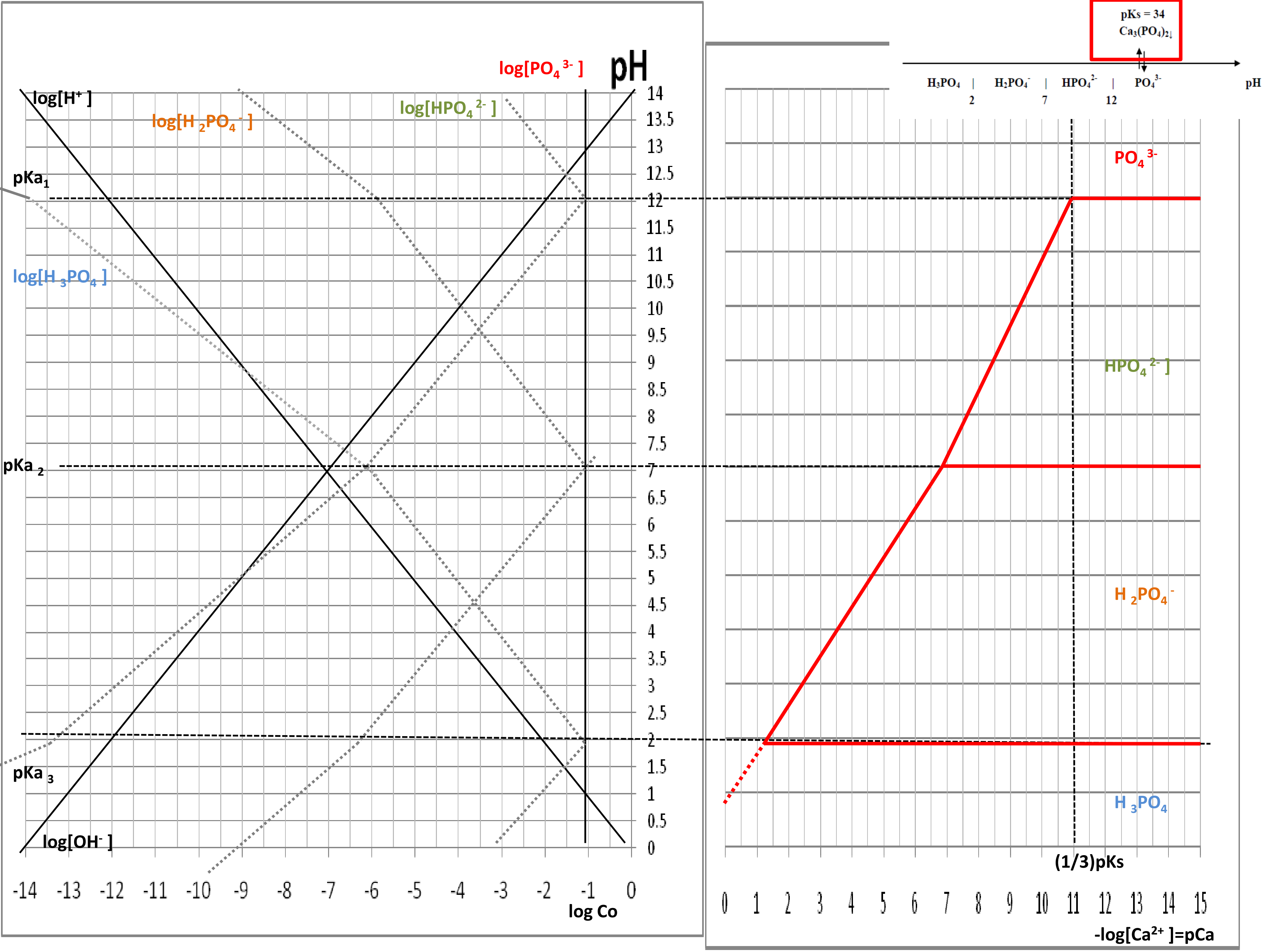
log[H⁺]
log[$H_2PO_4^-$]
log[HPO_4^{2-}]
log[PO_4^{3-}]
pH
pKa1
pKa 2
pKa 3
log[H_3PO_4]
log[OH⁻]
log Co
pKs = 34
$Ca_3(PO_4)_2$↓
H_3PO_4
$H_2PO_4^-$
HPO_4^{2-}
PO_4^{3-}
2
7
12
PO_4^{3-}
HPO_4^{2-}]
H $_2PO_4^-$
H $_3PO_4$
(1/3)pKs
-log[Ca^{2+}]=pCa



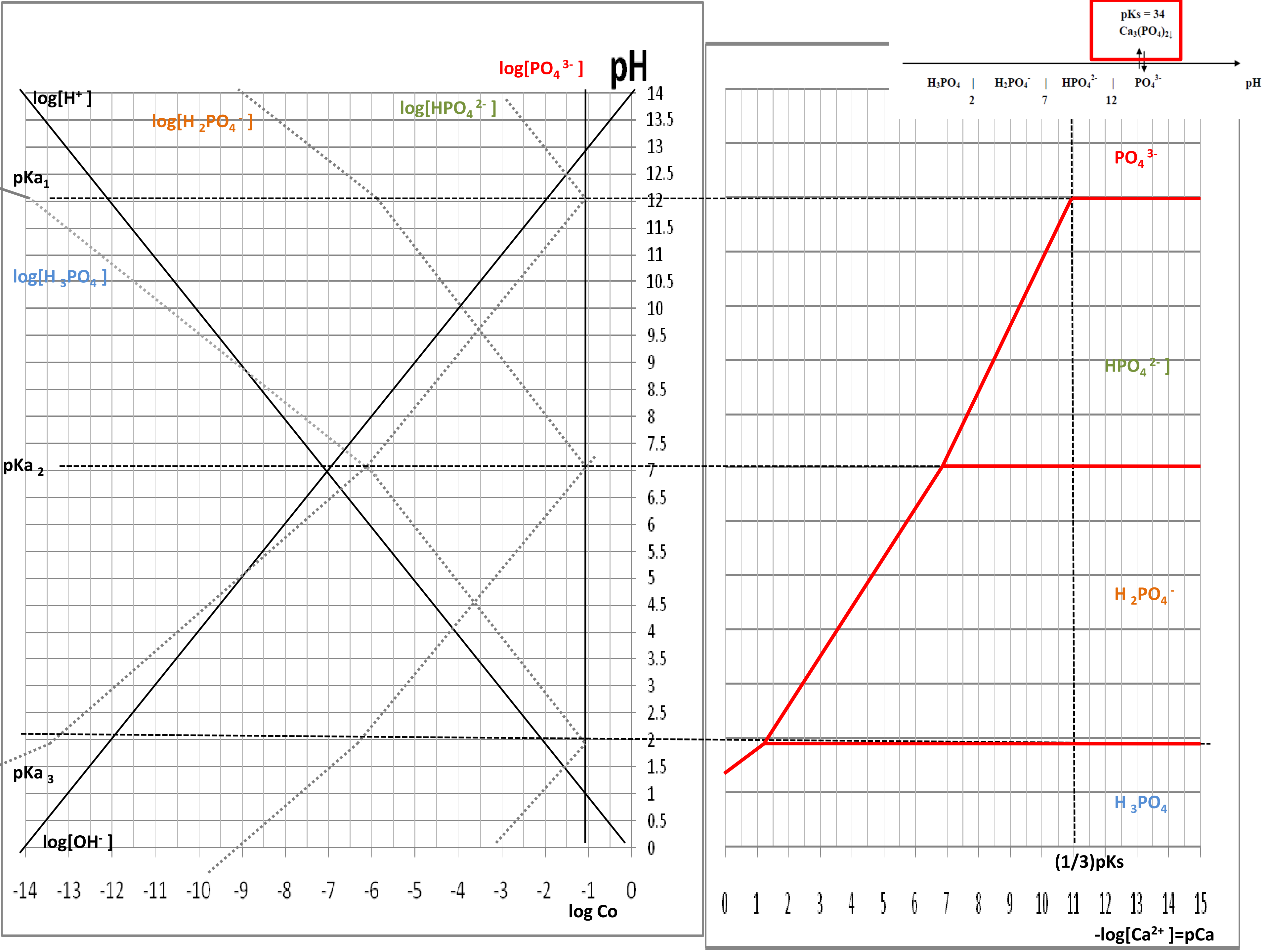
pH
log[PO4 3-]
log[H+]
log[H 2PO4 -]
log[HPO4 2-]
pKa1
log[H 3PO4]
pKa 2
pKa 3
log[OH-]
log Co
pKs = 34
Ca3(PO4)2↓
H3PO4
H2PO4-
HPO4 2-
PO4 3-
pH
2
7
12
PO4 3-
HPO4 2-]
H 2PO4 -
H 3PO4
(1/3)pKs
-log[Ca2+]=pCa

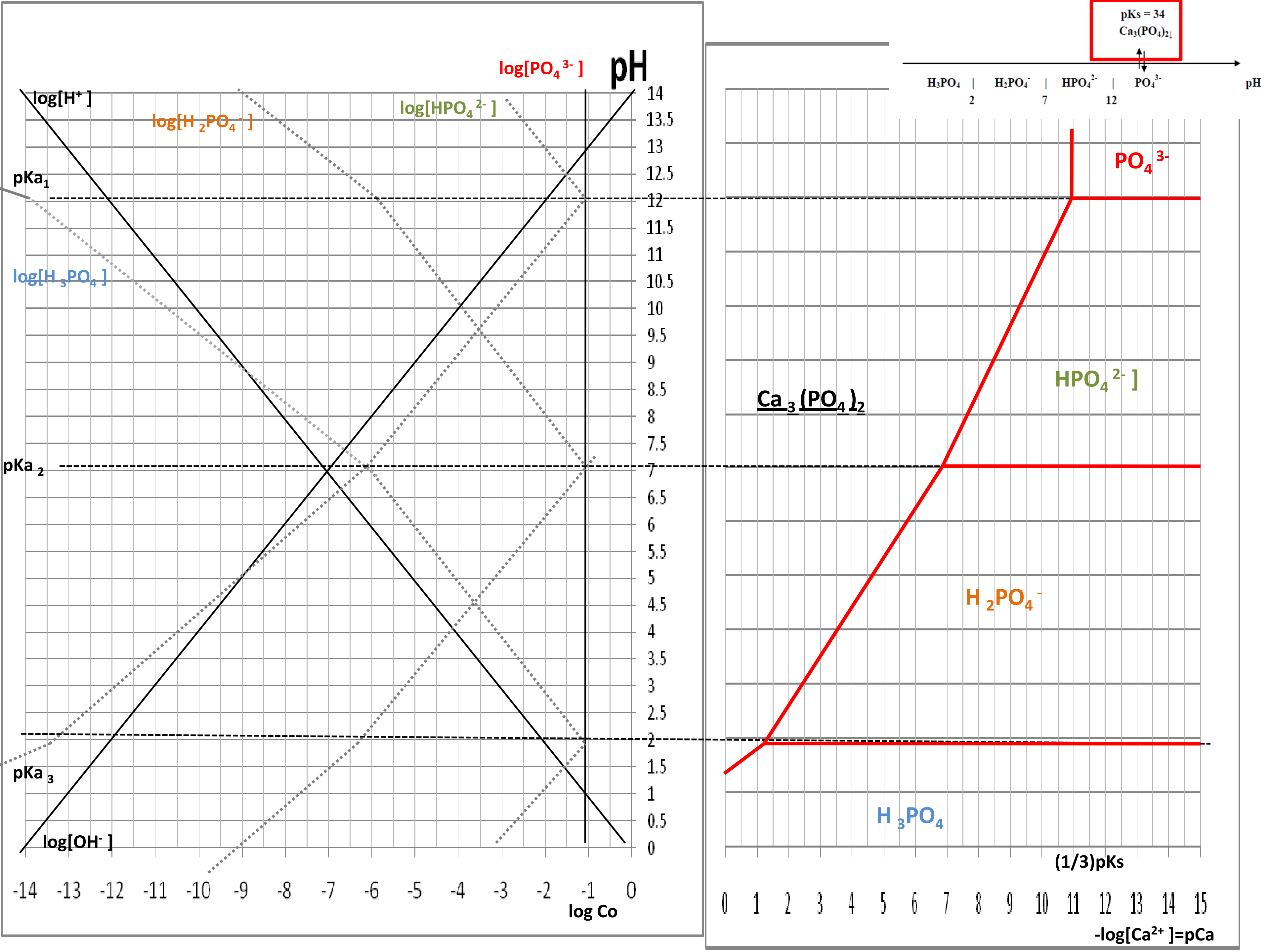


pH
log[H+]
log[H 2PO4-]
log[HPO4 2-]
log[PO4 3-]
log[H 3PO4]
log[OH-]
pKa1
pKa 2
pKa 3
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
log Co
pKs = 34
Ca3(PO4)2↓
H3PO4 | H2PO4- | HPO4 2- | PO4 3-
2
7
12
pH
PO4 3-
HPO4 2-]
H 2PO4 -
H 3PO4
(1/3)pKs
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
-log[Ca2+]=pCa

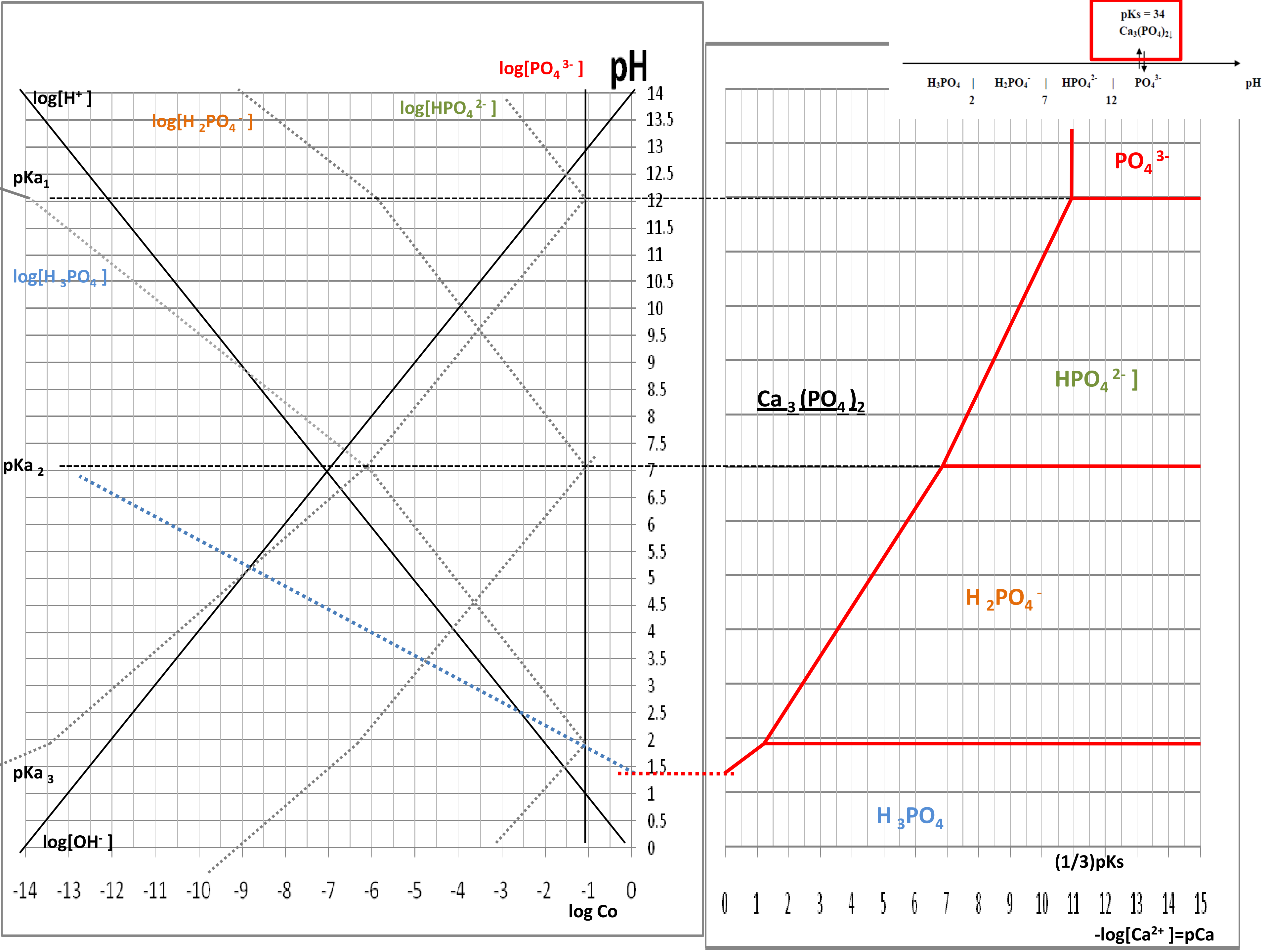


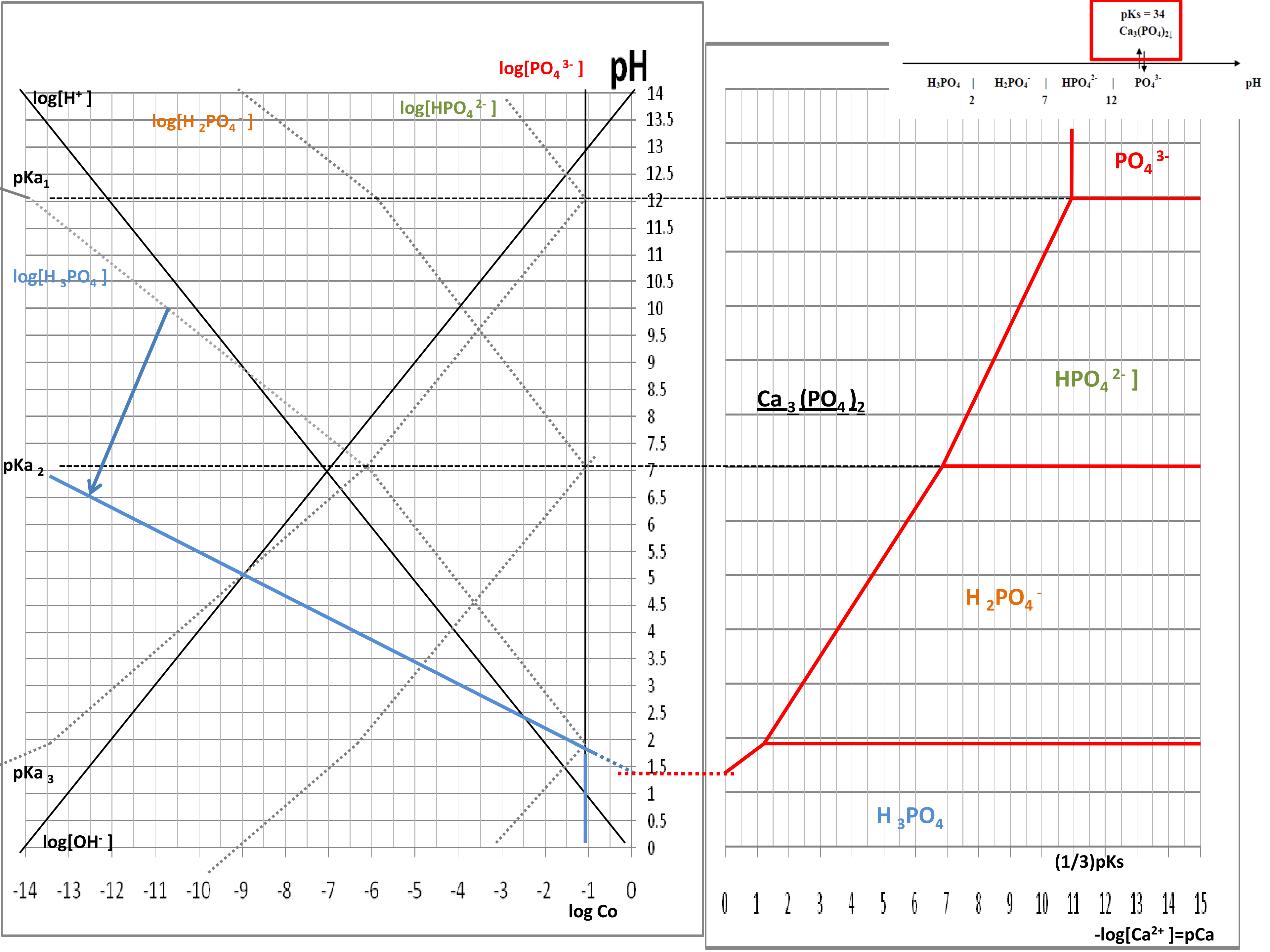
$pK_s = 34$
$Ca_3(PO_4)_2\downarrow$
H_3PO_4 | $H_2PO_4^-$ | HPO_4^{2-} | PO_4^{3-} pH
2
7
12
pH
$\log[PO_4^{3-}]$
$\log[H^+]$
$\log[H_2PO_4^-]$
$\log[HPO_4^{2-}]$
pKa_1
$\log[H_3PO_4]$
pKa_2
pKa_3
$\log[OH^-]$
log Co
PO_4^{3-}
HPO_4^{2-}]
$H_2PO_4^-$
H_3PO_4
(1/3)pKs
$-\log[Ca^{2+}]=pCa$


pH
log[H+]
log[H 2PO4 -]
log[HPO4 2-]
log[PO4 3-]
log[H 3PO4]
log[OH-]
pKa1
pKa 2
pKa 3
log Co
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
pKs = 34
Ca3(PO4)2↓
H3PO4 | H2PO4- | HPO4 2- | PO4 3-
2
7
12
pH
PO4 3-
HPO4 2-]
H 2PO4 -
H 3PO4
(1/3)pKs
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
-log[Ca2+]=pCa

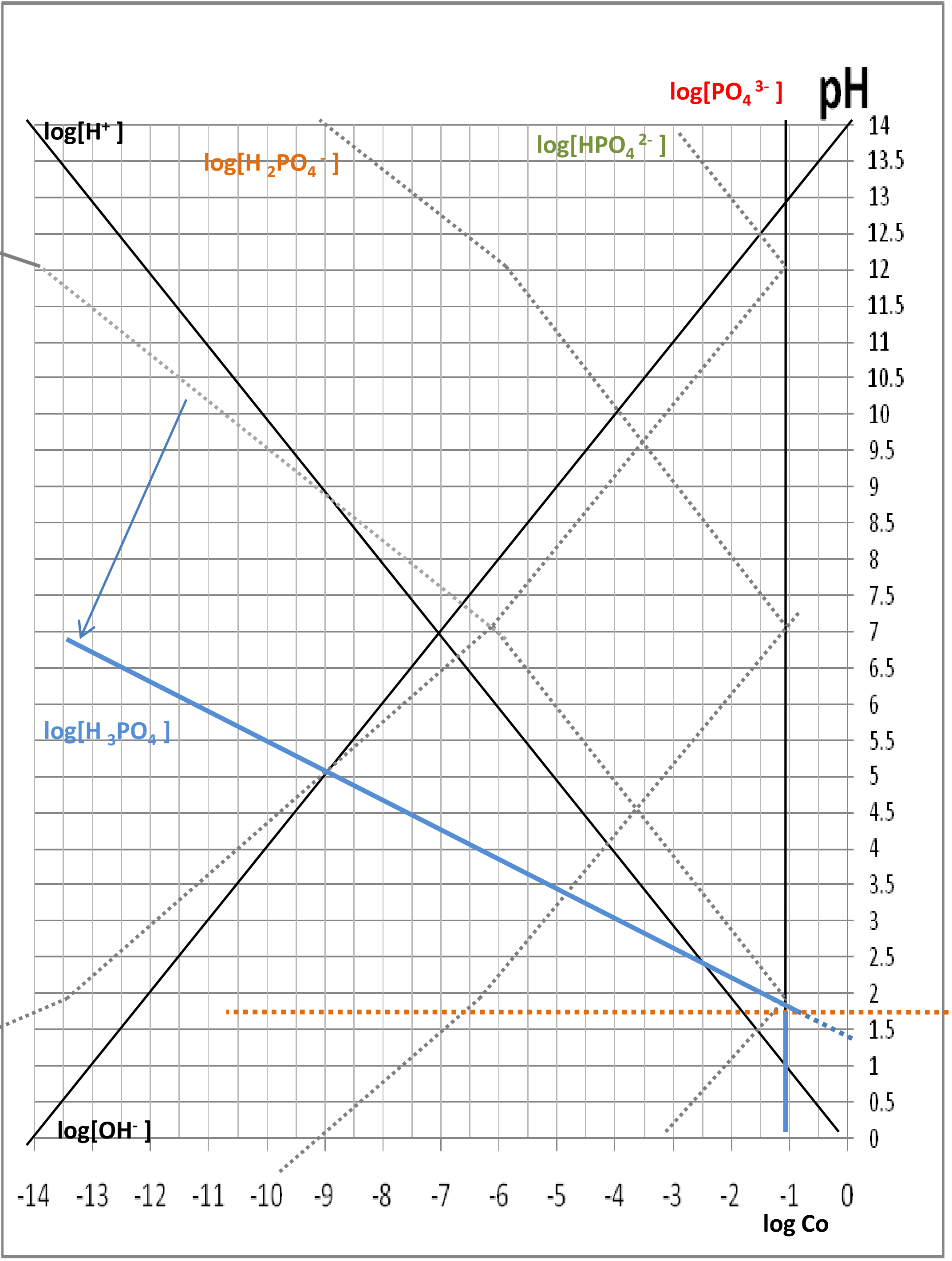


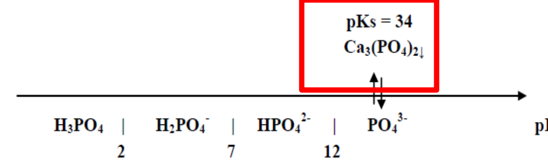
pKs = 34
$Ca_3(PO_4)_{2\downarrow}$
H_3PO_4 | $H_2PO_4^-$ | HPO_4^{2-} | PO_4^{3-}
2
7
12
pH
log[PO_4^{3-}]
pH
log[H^+]
log[$H_2PO_4^-$]
log[HPO_4^{2-}]
pKa$_1$
log[H_3PO_4]
pKa $_2$
pKa $_3$
log[OH^-]
log Co
PO_4^{3-}
HPO_4^{2-}]
$Ca_3(PO_4)_2$
$H_2PO_4^-$
H_3PO_4
(1/3)pKs
-log[Ca^{2+}]=pCa

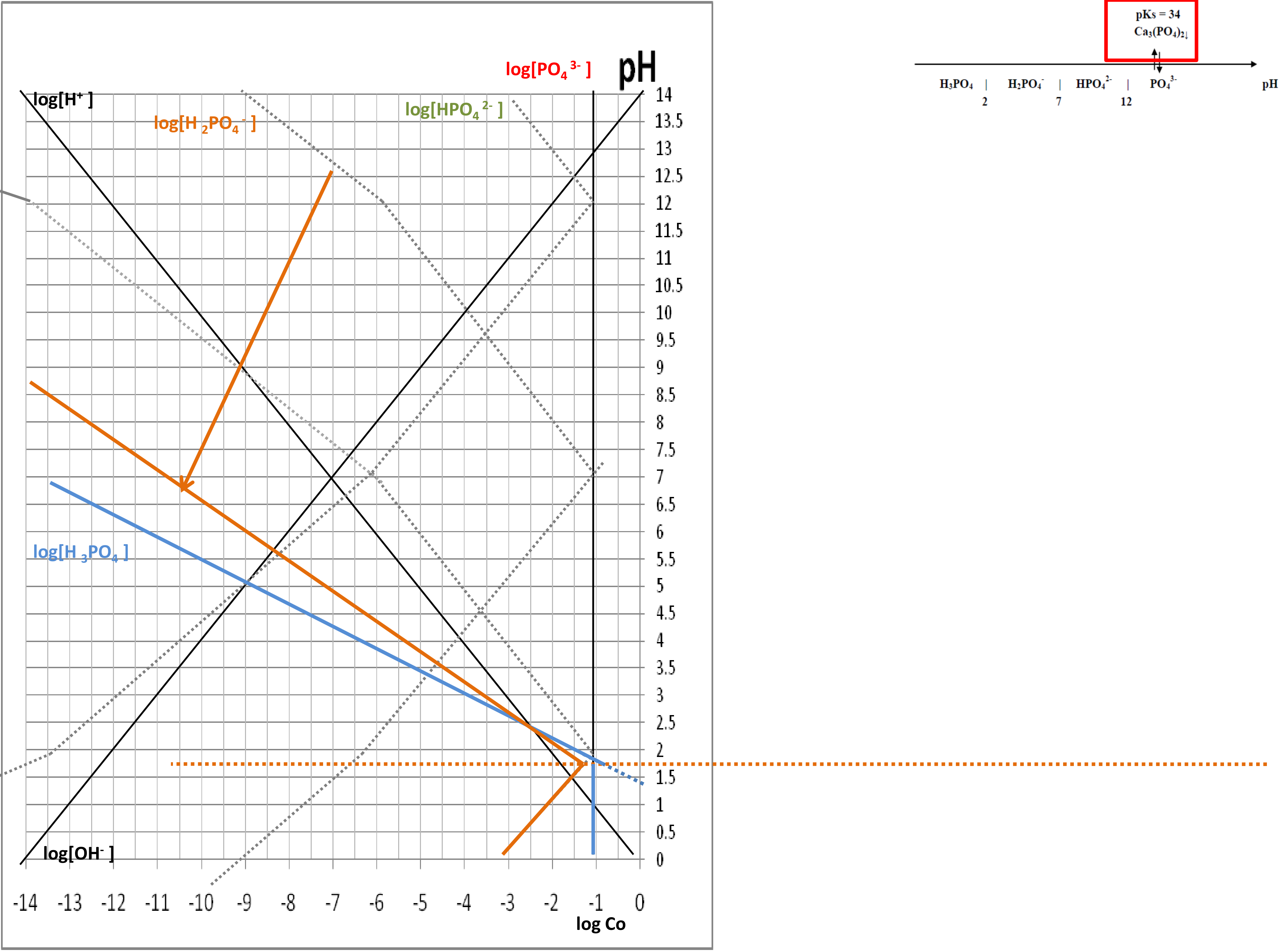

pH
$\log[H^+]$
$\log[H_2PO_4^-]$
$\log[HPO_4^{2-}]$
$\log[PO_4^{3-}]$
pKa_1
$\log[H_3PO_4]$
pKa_2
pKa_3
$\log[OH^-]$
14 13.5 13 12.5 12 11.5 11 10.5 10 9.5 9 8.5 8 7.5 7 6.5 6 5.5 5 4.5 4 3.5 3 2.5 2 1.5 1 0.5 0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
log Co
pKs = 34
$Ca_3(PO_4)_2\downarrow$
H_3PO_4 | $H_2PO_4^-$ | HPO_4^{2-} | PO_4^{3-}
2 7 12
pH
PO_4^{3-}
HPO_4^{2-}]
$Ca_3(PO_4)_2$
$H_2PO_4^-$
H_3PO_4
(1/3)pKs
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
$-\log[Ca^{2+}]=pCa$



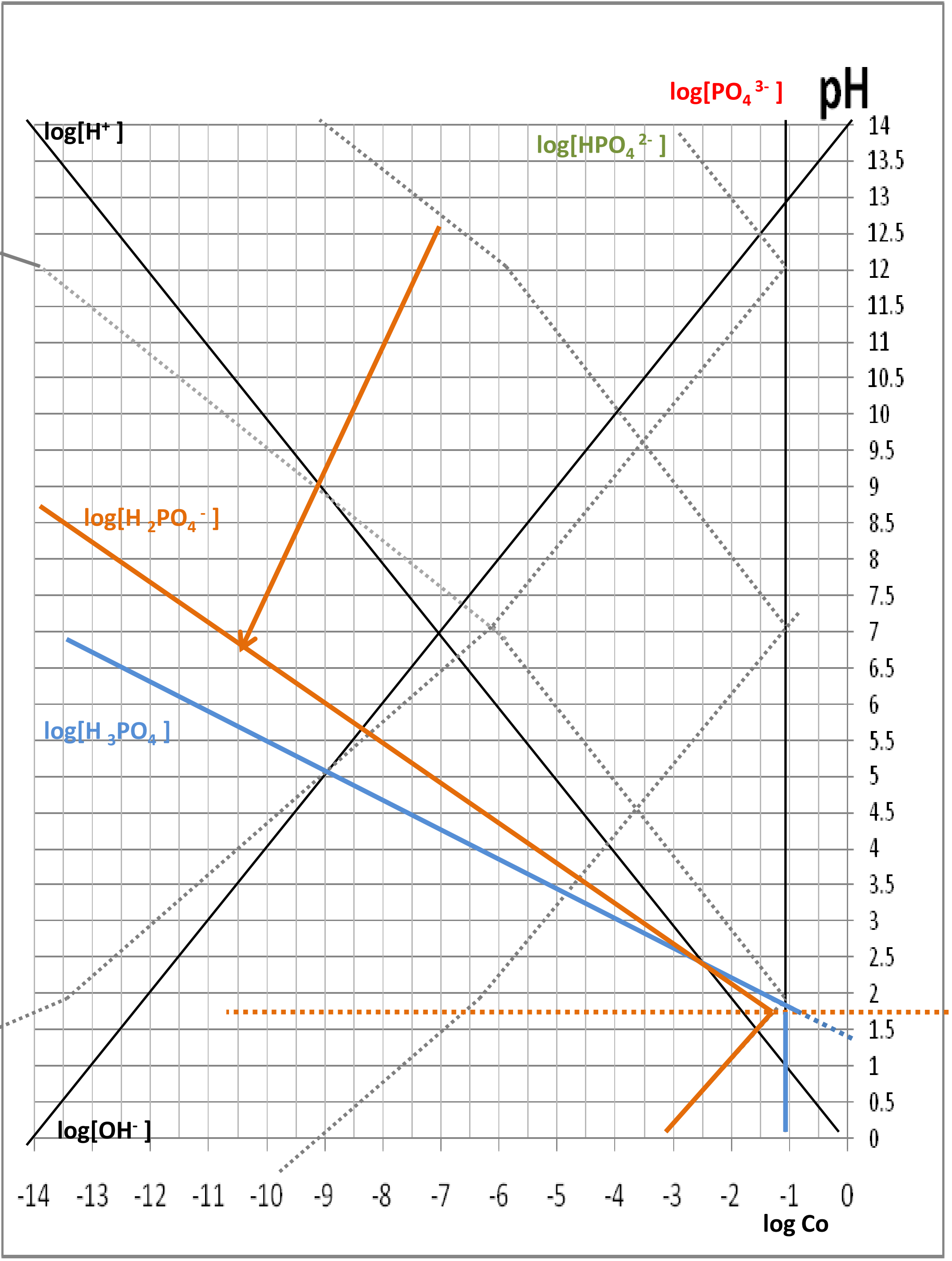
pKs = 34
$Ca_3(PO_4)_2\downarrow$
H_3PO_4 | $H_2PO_4^-$ | HPO_4^{2-} | PO_4^{3-} pH
2 7 12
log[PO_4^{3-}]
pH
log[H^+]
log[$H_2PO_4^-$]
log[HPO_4^{2-}]
pKa_1
log[H_3PO_4]
pKa_2
pKa_3
log[OH^-]
log Co
PO_4^{3-}
HPO_4^{2-}]
$Ca_3(PO_4)_2$
$H_2PO_4^-$
H_3PO_4
(1/3)pKs
-log[Ca^{2+}]=pCa


log[H+]
log[H 2PO4-]
log[HPO4 2-]
log[PO4 3-]
pH
log[H 3PO4]
log[OH-]
log Co
14 13.5 13 12.5 12 11.5 11 10.5 10 9.5 9 8.5 8 7.5 7 6.5 6 5.5 5 4.5 4 3.5 3 2.5 2 1.5 1 0.5 0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0

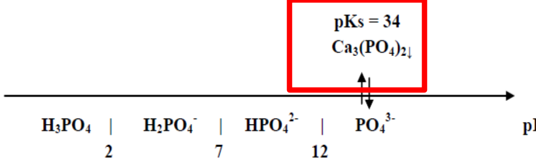

pKs = 34
Ca3(PO4)2↓
H3PO4
H2PO4-
HPO42-
PO43-
pH
2
7
12



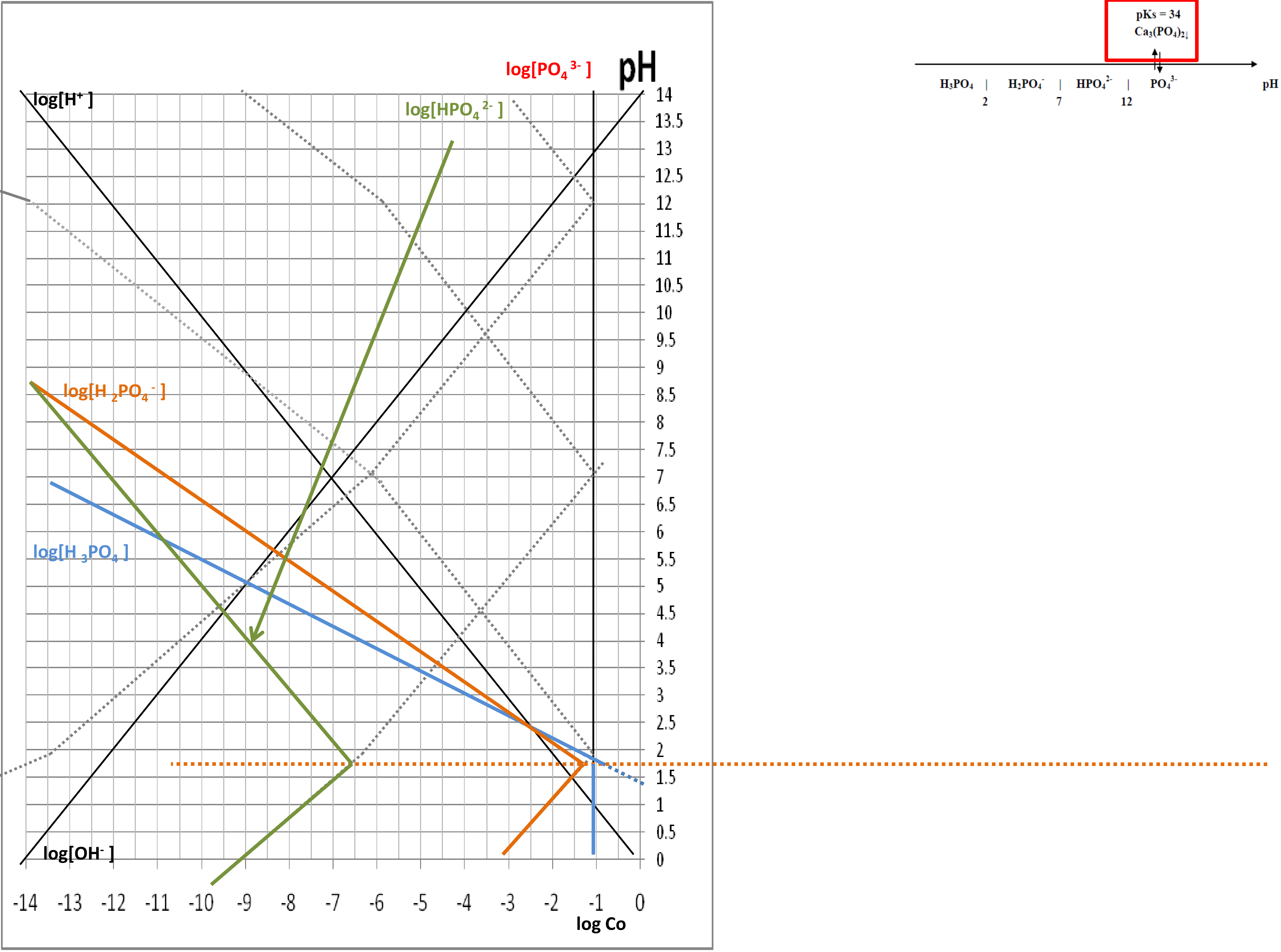
pKs = 34
$Ca_3(PO_4)_2\downarrow$
H_3PO_4
$H_2PO_4^-$
HPO_4^{2-}
PO_4^{3-}
pH
2
7
12
log[PO_4^{3-}]
pH
log[H^+]
log[$H_2PO_4^-$]
log[HPO_4^{2-}]
log[H_3PO_4]
log[OH^-]
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
log Co



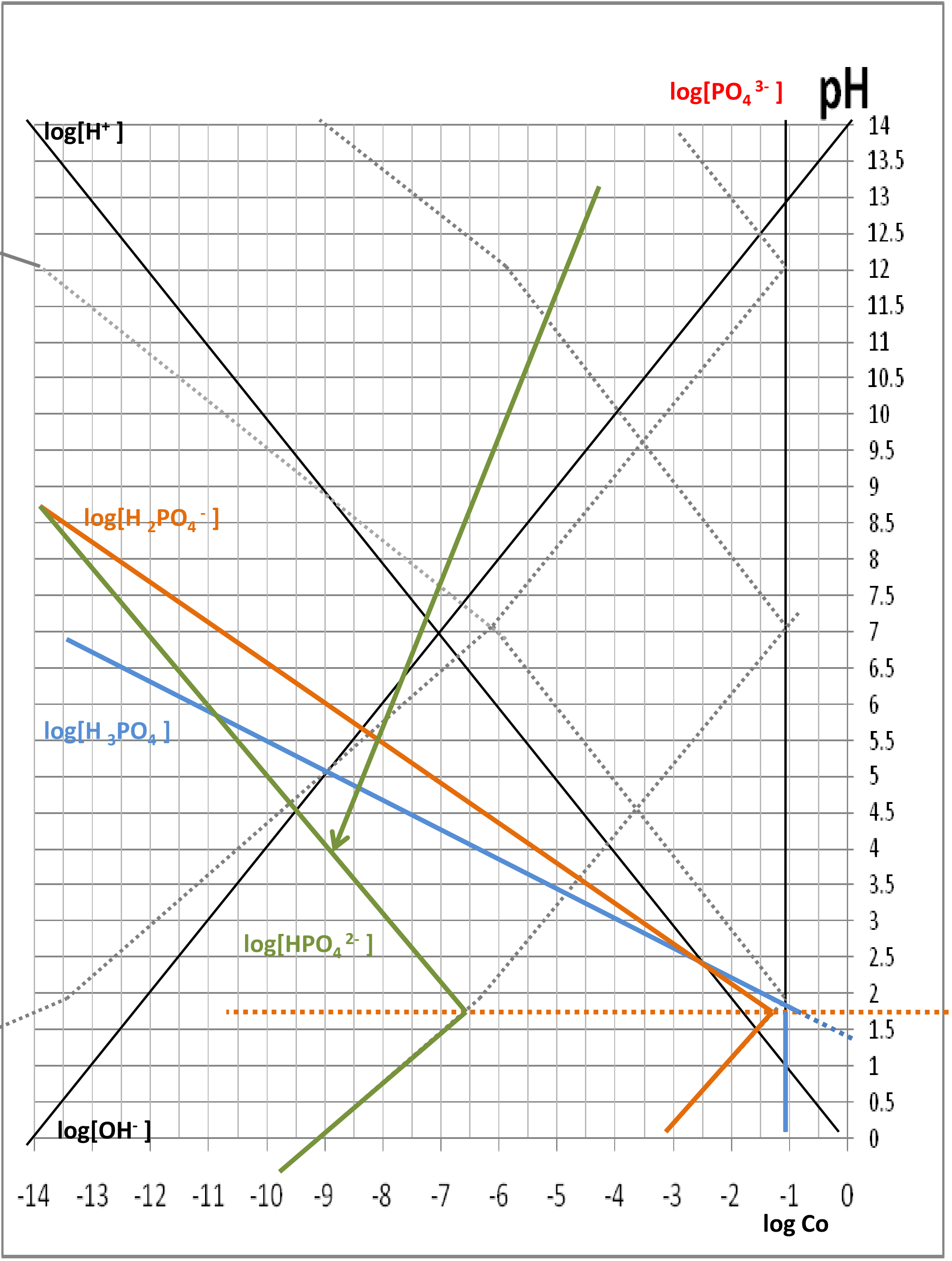
pH
log[PO_4^{3-}]
log[H^+]
log[HPO_4^{2-}]
log[$H_2PO_4^-$]
log[H_3PO_4]
log[OH^-]
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
log Co



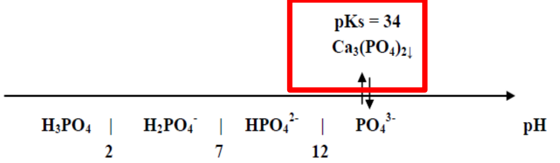
pKs = 34
$Ca_3(PO_4)_2\downarrow$
H_3PO_4
$H_2PO_4^-$
HPO_4^{2-}
PO_4^{3-}
pH
2
7
12



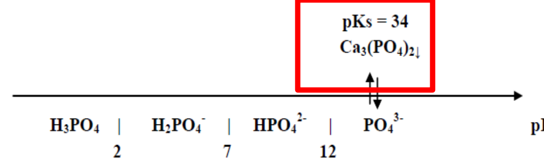
pKs = 34
Ca3(PO4)2↓
H3PO4
H2PO4-
HPO42-
PO43-
2
7
12
pH
log[PO4 3-]
pH
log[HPO4 2-]
log[H+]
log[H 2PO4 -]
log[H 3PO4]
log[OH-]
log Co
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0

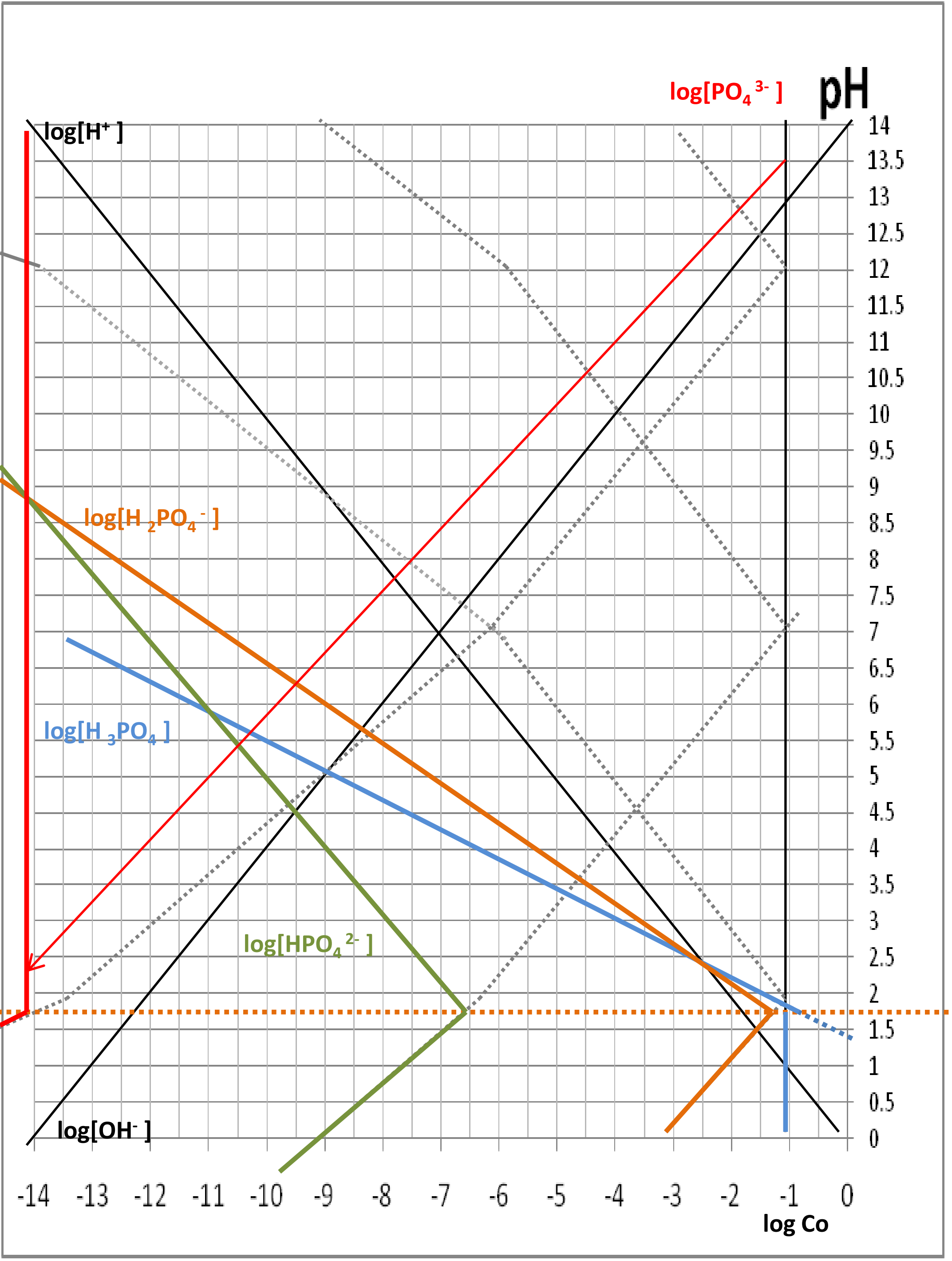


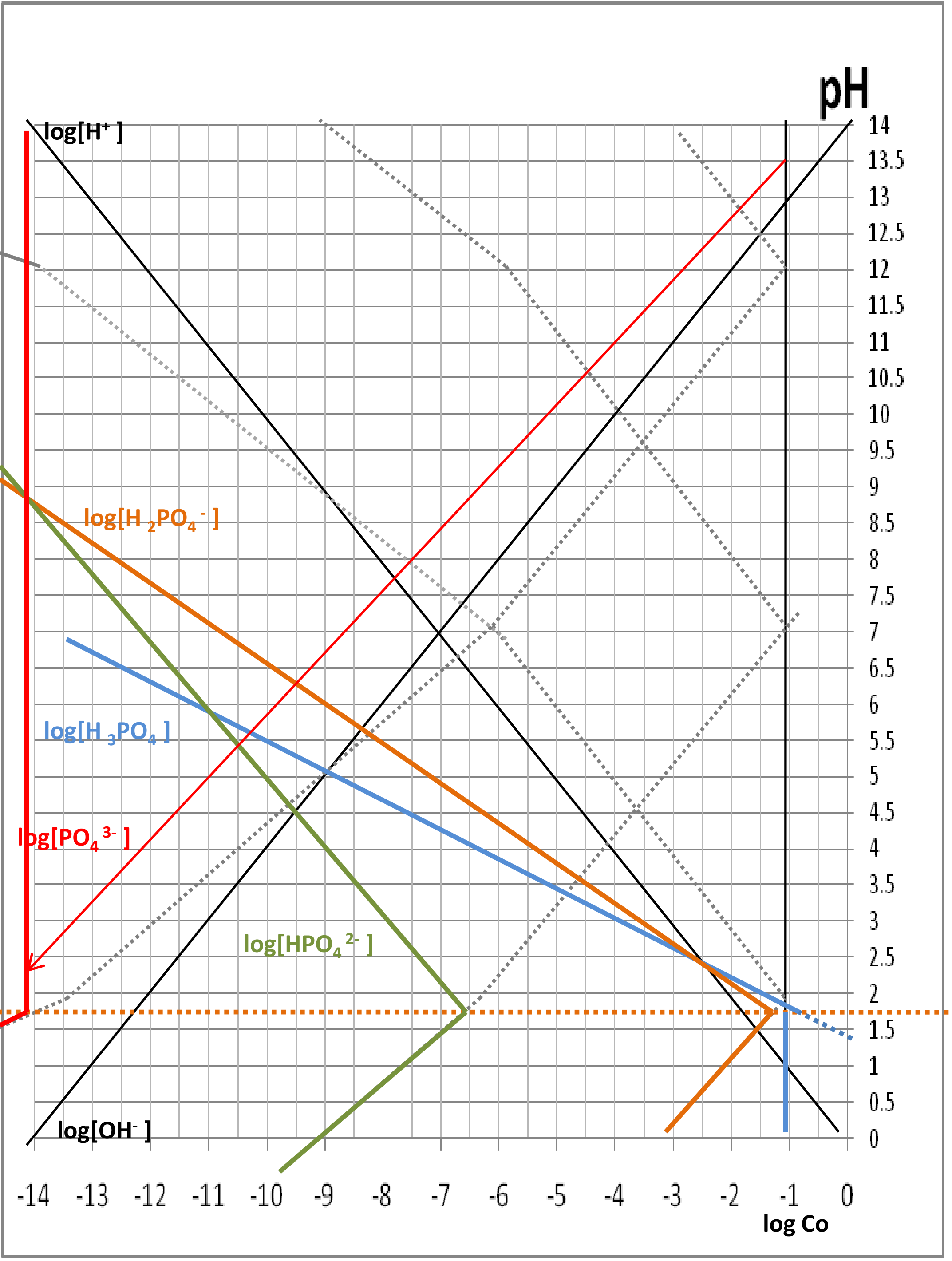
pH
log[PO4 3-]
log[H+]
log[H 2PO4 -]
log[H 3PO4]
log[HPO4 2-]
log[OH-]
log Co
14 13.5 13 12.5 12 11.5 11 10.5 10 9.5 9 8.5 8 7.5 7 6.5 6 5.5 5 4.5 4 3.5 3 2.5 2 1.5 1 0.5 0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0

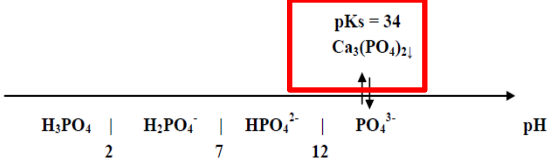


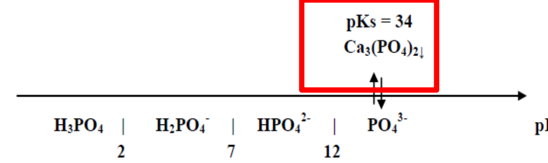
pKs = 34
Ca3(PO4)2↓
H3PO4
H2PO4-
HPO4 2-
PO4 3-
pH
2
7
12

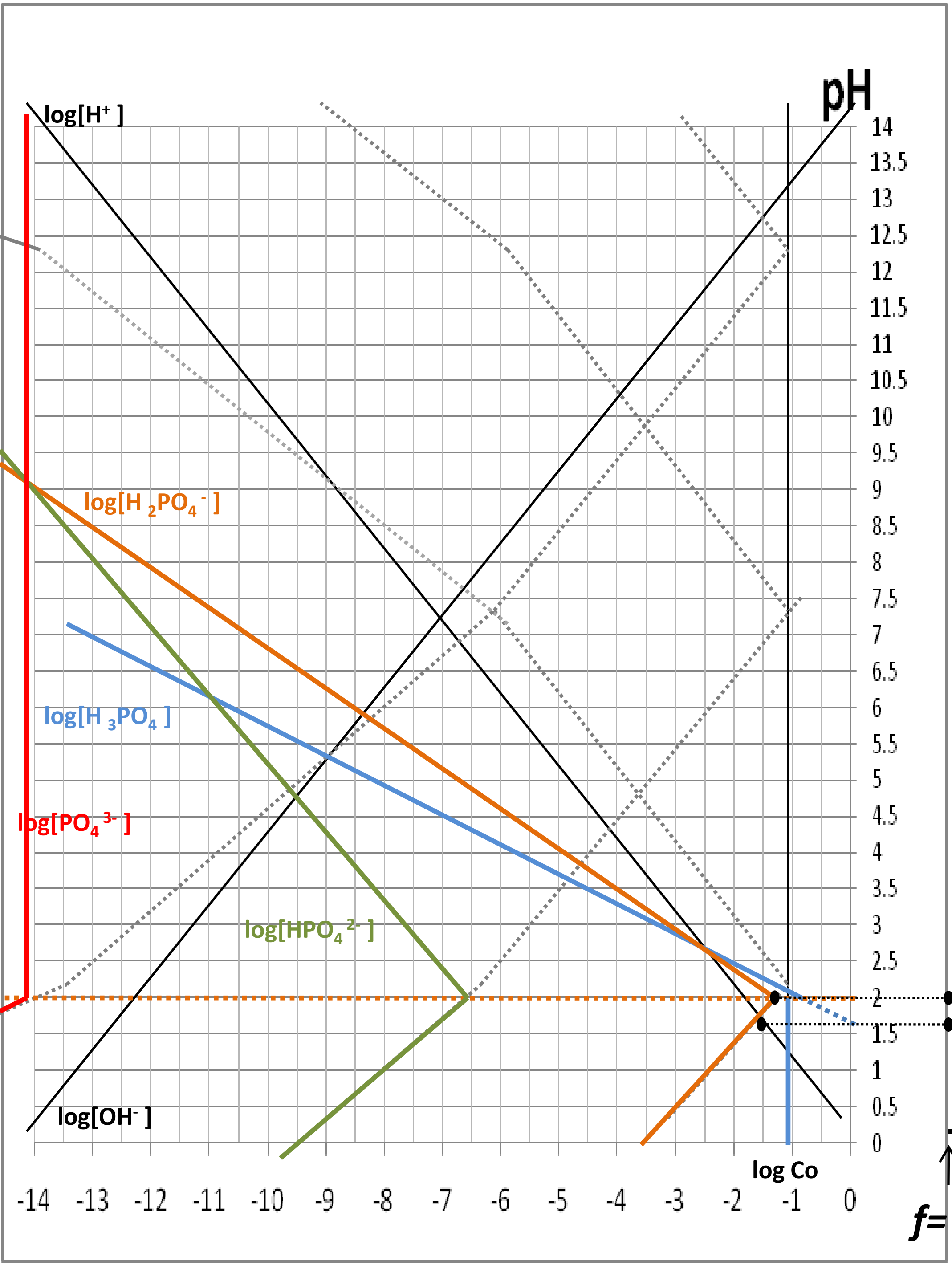

pKs = 34
Ca3(PO4)2↓
H3PO4
H2PO4-
HPO42-
PO43-
pH
2
7
12


log[PO4 3-]
pH
log[H+]
log[H 2PO4 -]
log[H 3PO4]
log[HPO4 2-]
log[OH-]
log Co
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0


pH
log[H+]
log[H 2PO4 -]
log[H 3PO4]
log[PO4 3-]
log[HPO4 2-]
log[OH-]
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
log Co


pKs = 34
Ca3(PO4)2↓
H3PO4
H2PO4-
HPO42-
PO43-
pH
2
7
12





$$2H_3PO_4 + 3Ca^{2+} + 6OH^- \leftrightarrows \underline{Ca_3(PO_4)_{2\downarrow}} + 6H_2O \quad K = 10^{76}$$

pKs = 76

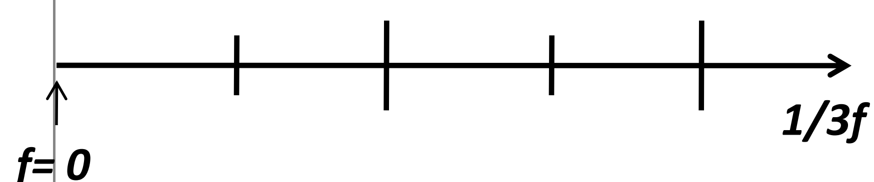
$$Ks = 10^{-76} = \left[\frac{CoVo}{Vo + v_{ip}}\right]^2 \left[\frac{v_{ip}C_{OH}}{Vo + v_{ip}}\right]^6$$

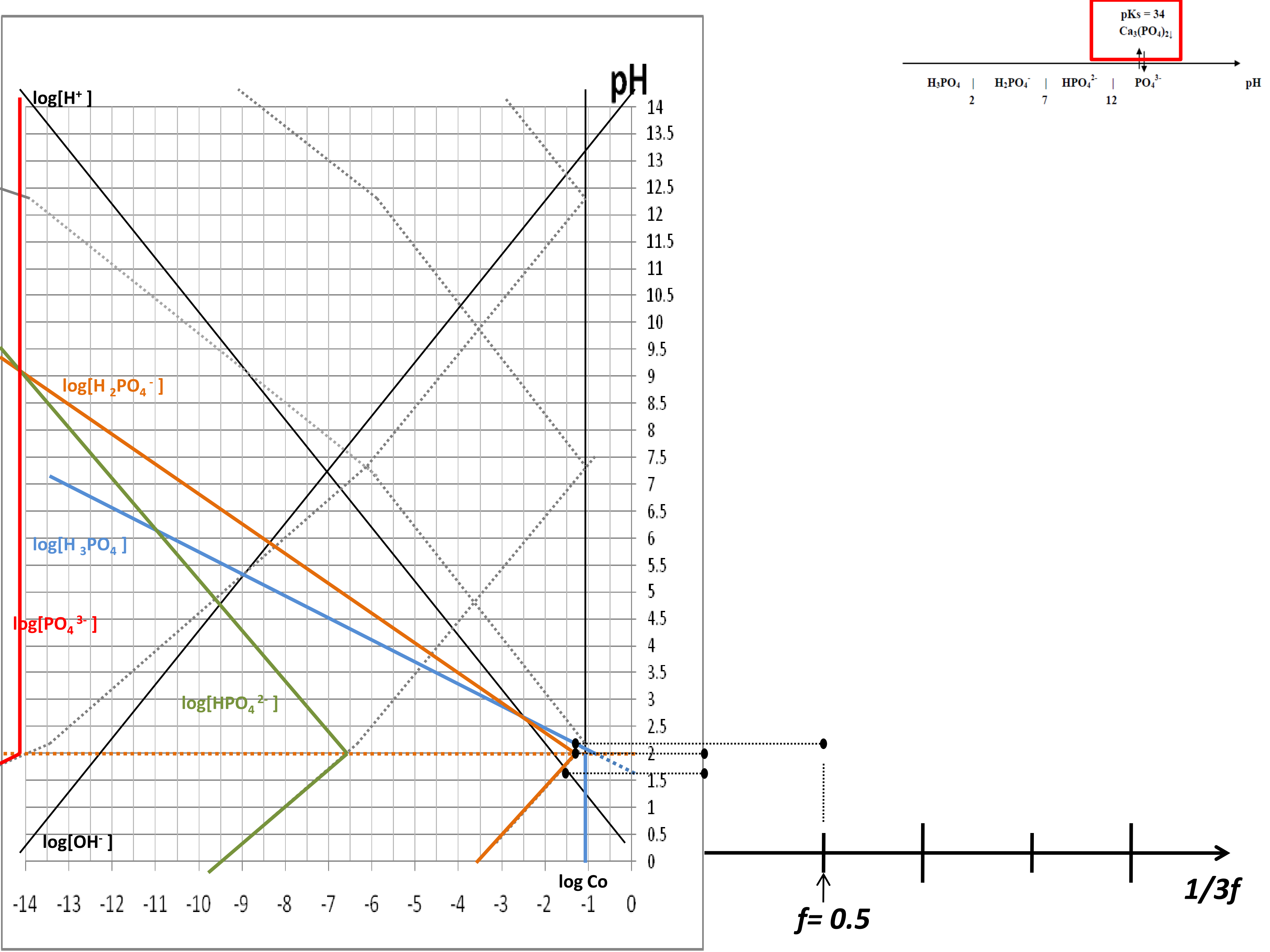
$$Co = C_{OH}$$

$$V_0 + v_{ip} \approx V_0$$

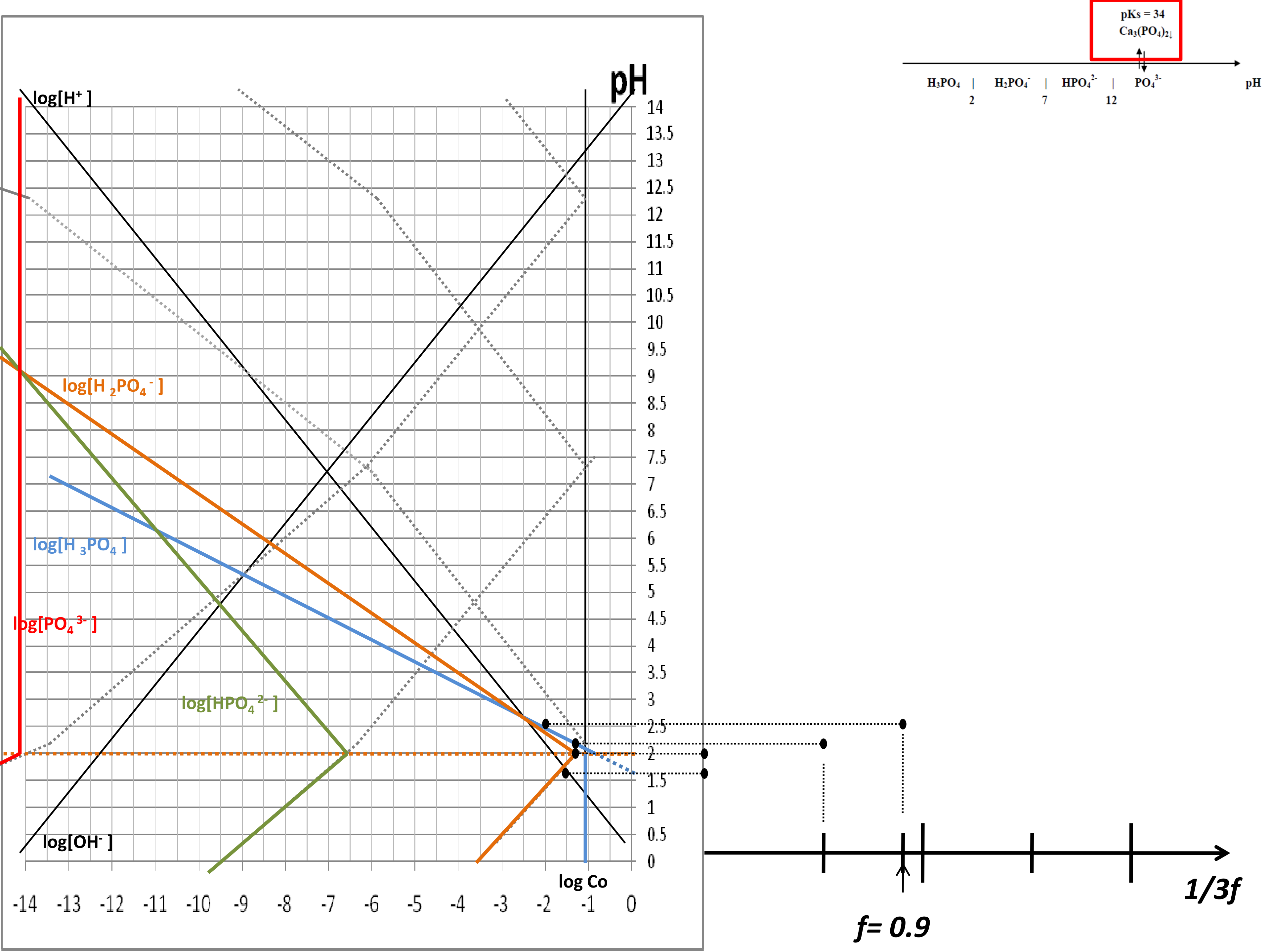
$$Ks = 10^{-76} = \left[\frac{Co}{1}\right]^2 \left[\frac{v_{ip}C_0}{Vo}\right]^6$$

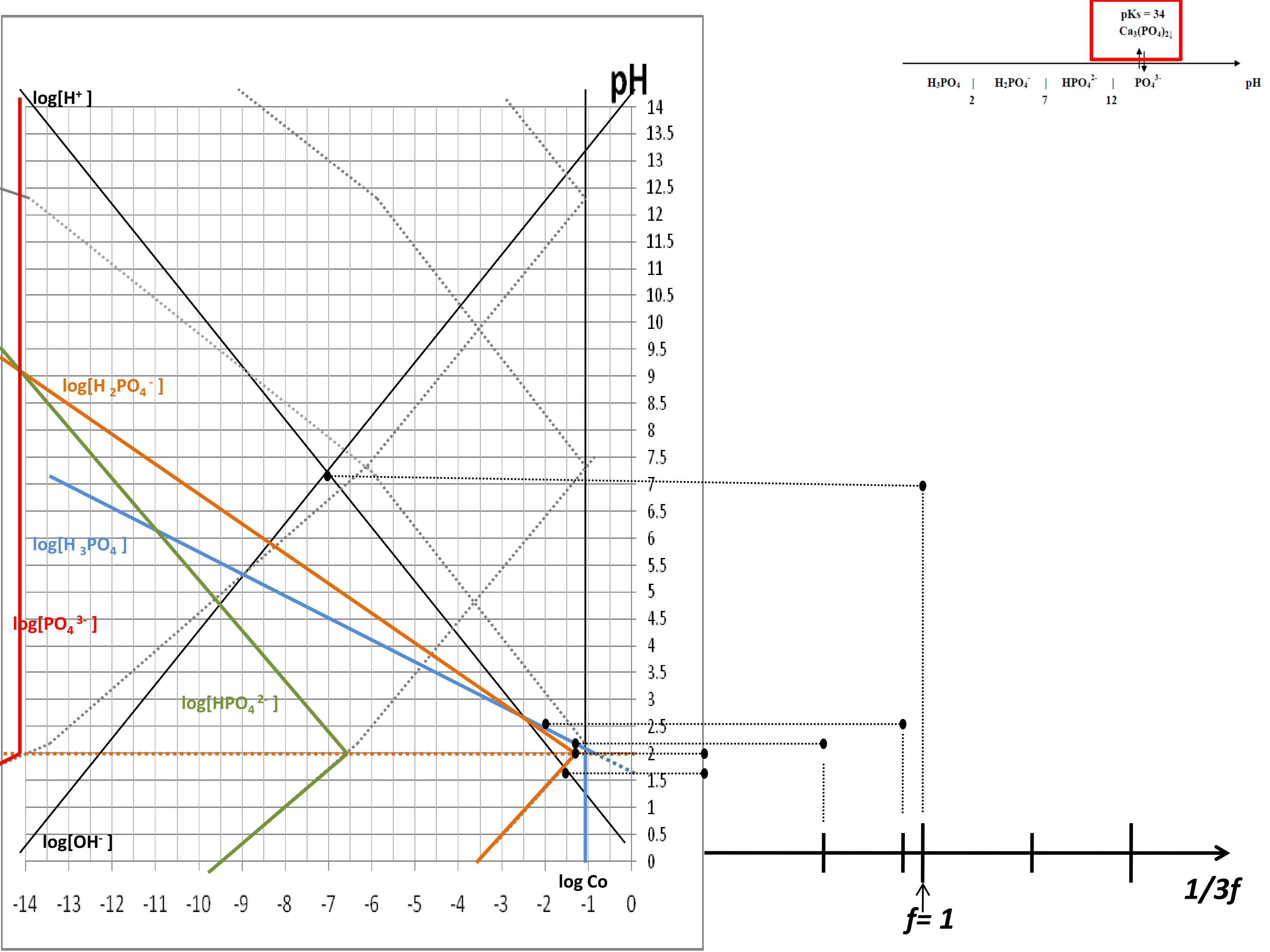
$$\left[\frac{v_{ip}}{V_0}\right] = f = 10^{-11.3} \approx 0$$



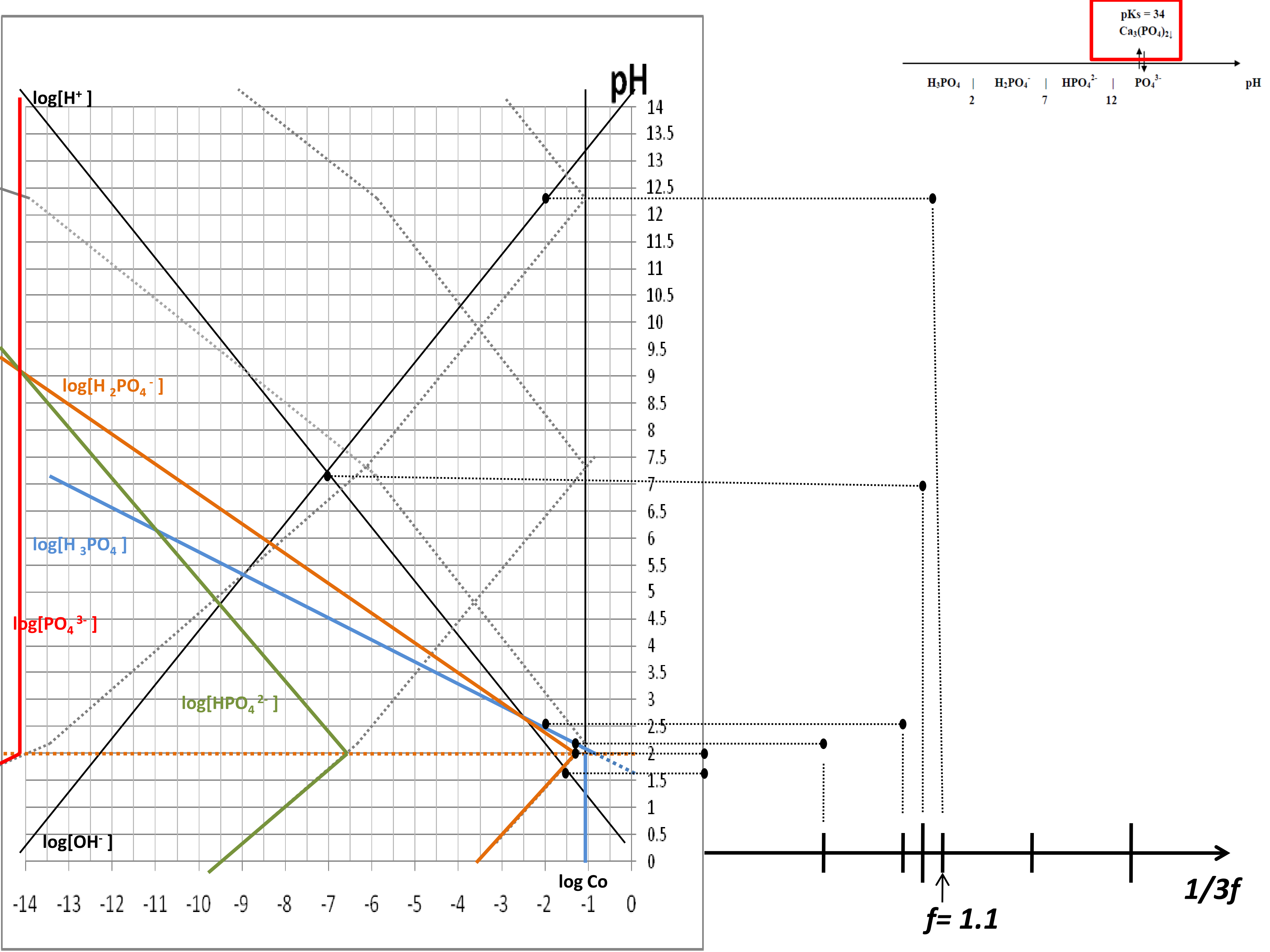


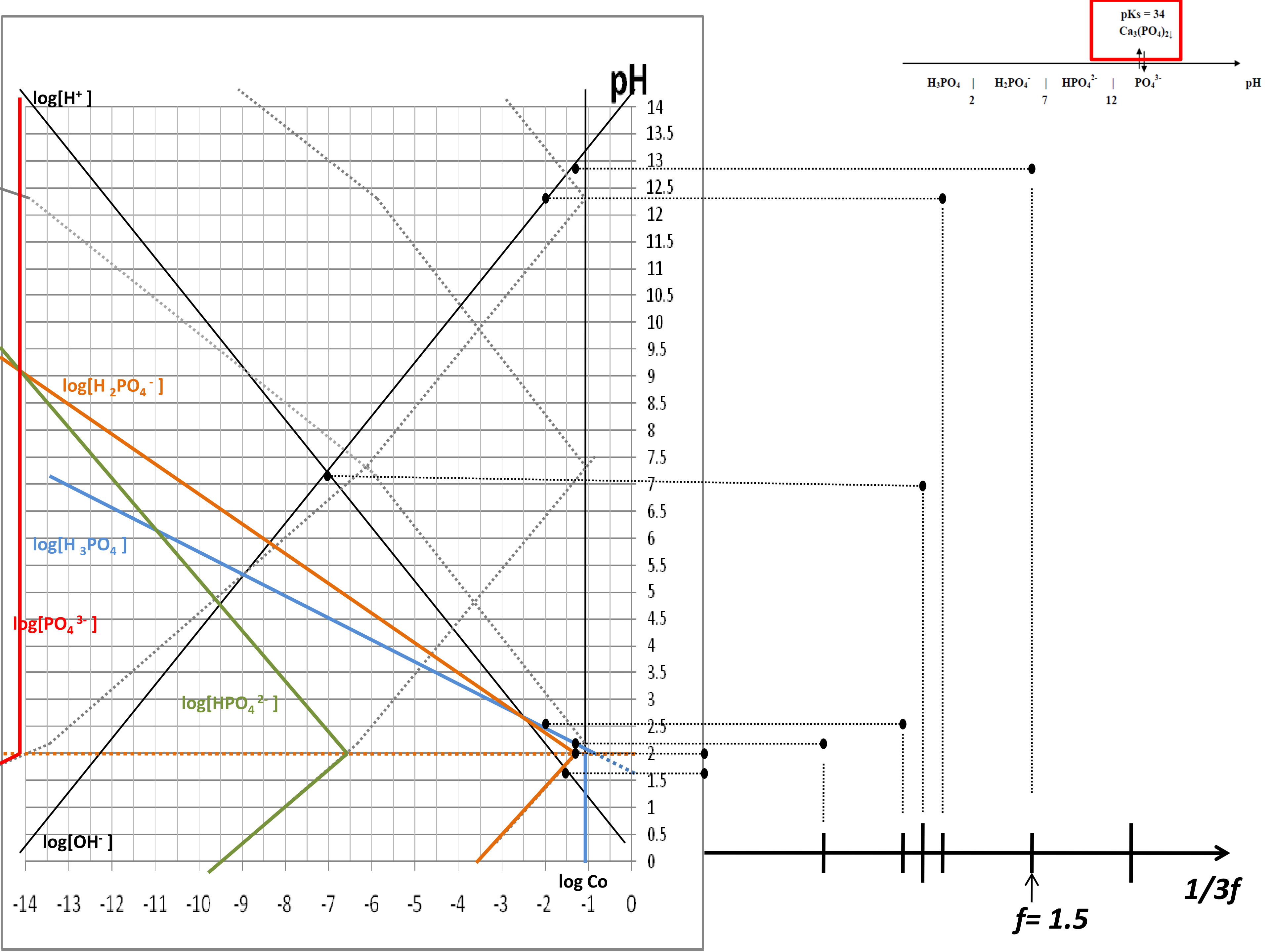
pKs = 34
Ca3(PO4)2↓
H3PO4
H2PO4-
HPO42-
PO43-
pH
2
7
12
pH
log[H+]
log[H 2PO4 -]
log[H 3PO4]
log[PO4 3-]
log[HPO4 2-]
log[OH-]
log Co
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
f= 0.5
1/3f


pKs = 34
Ca3(PO4)2↓
H3PO4
H2PO4-
HPO4 2-
PO4 3-
pH
2
7
12
log[H+]
pH
log[H 2PO4 -]
log[H 3PO4]
log[PO4 3-]
log[HPO4 2-]
log[OH-]
log Co
14 13.5 13 12.5 12 11.5 11 10.5 10 9.5 9 8.5 8 7.5 7 6.5 6 5.5 5 4.5 4 3.5 3 2.5 2 1.5 1 0.5 0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
1/3f
f= 0.9

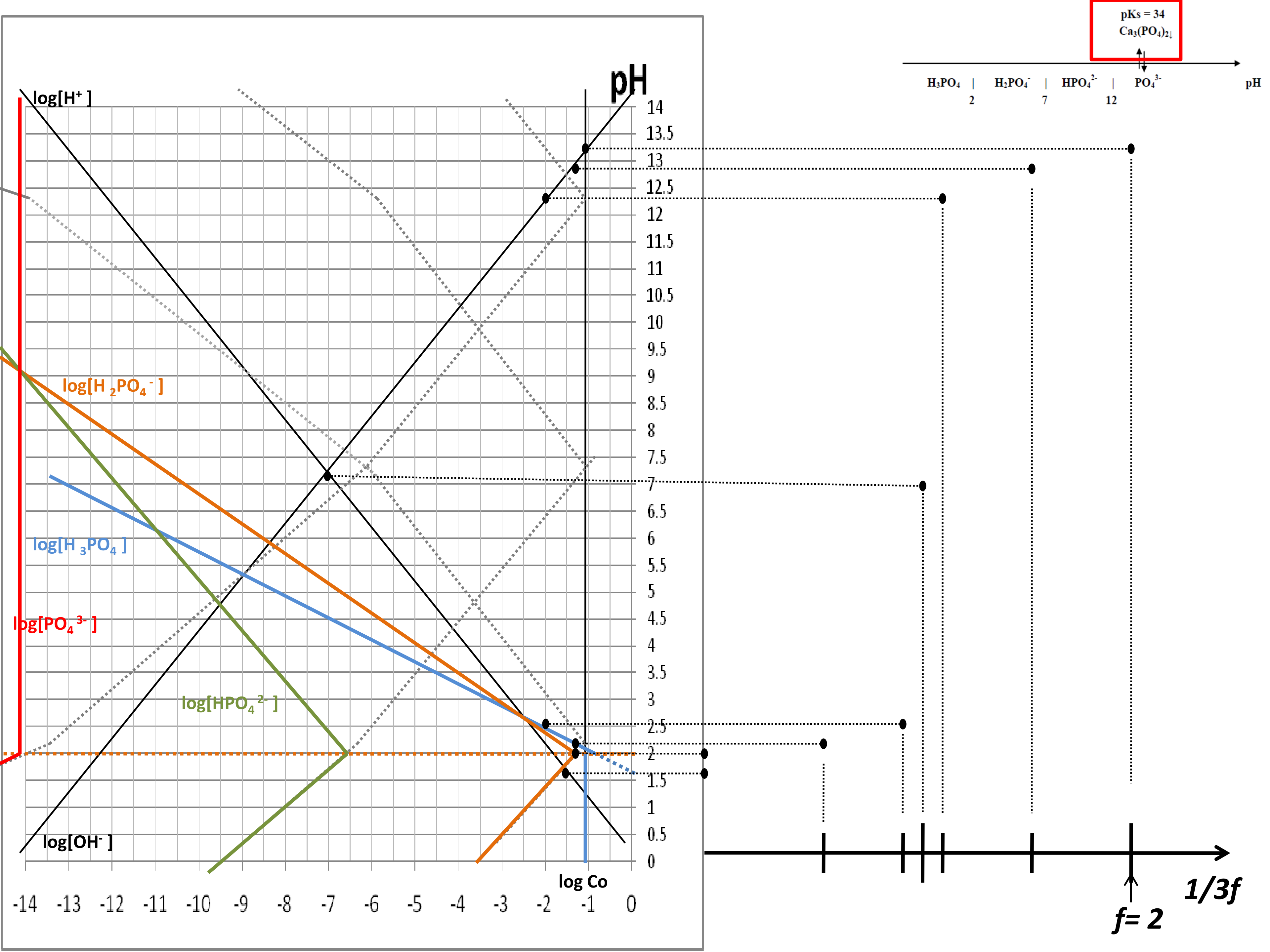


pKs = 34
$Ca_3(PO_4)_2\downarrow$
H_3PO_4 | $H_2PO_4^-$ | HPO_4^{2-} | PO_4^{3-} pH
2 7 12
pH
log[H+]
log[$H_2PO_4^-$]
log[H_3PO_4]
log[PO_4^{3-}]
log[HPO_4^{2-}]
log[OH-]
log Co
1/3f
f= 1

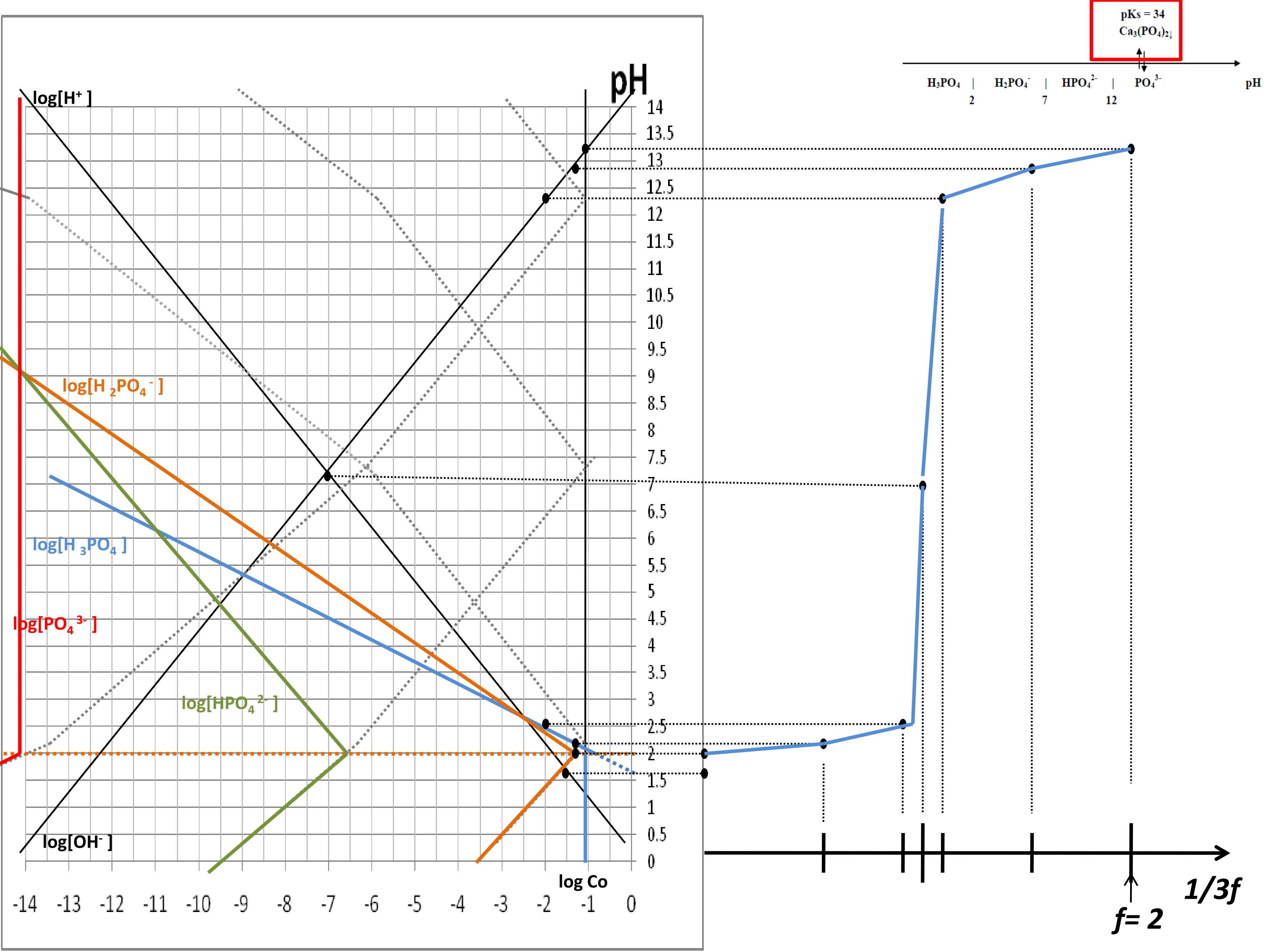

pKs = 34
Ca3(PO4)2↓
H3PO4
H2PO4-
HPO42-
PO43-
pH
2
7
12
pH
log[H+]
log[H 2PO4 -]
log[H 3PO4]
log[PO4 3-]
log[HPO4 2-]
log[OH-]
log Co
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1/3f
f= 1.1

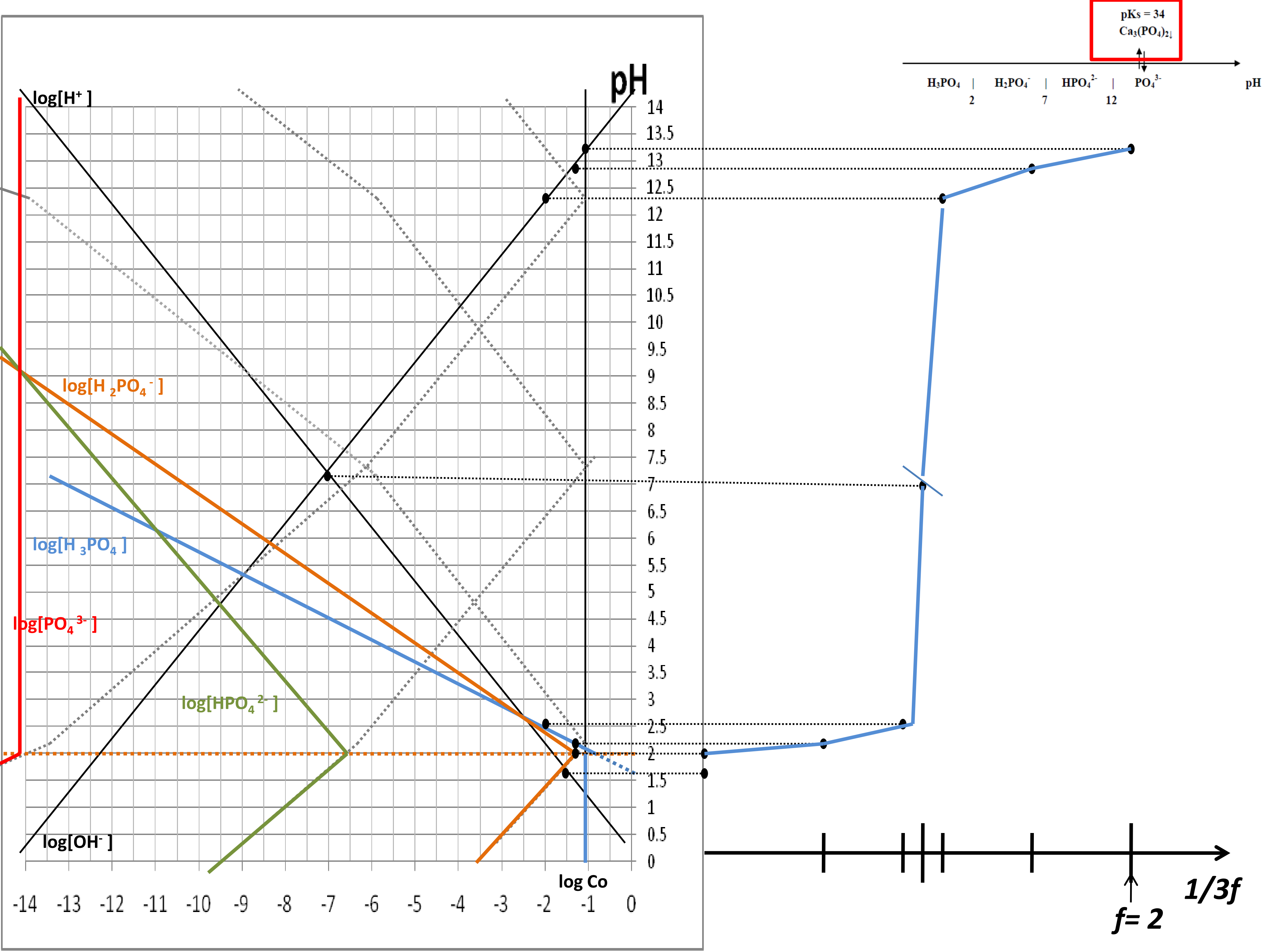


pKs = 34
$Ca_3(PO_4)_2\downarrow$
H_3PO_4
$H_2PO_4^-$
HPO_4^{2-}
PO_4^{3-}
pH
2
7
12
log[H⁺]
pH
log[$H_2PO_4^-$]
log[H_3PO_4]
log[PO_4^{3-}]
log[HPO_4^{2-}]
log[OH⁻]
log Co
14 13.5 13 12.5 12 11.5 11 10.5 10 9.5 9 8.5 8 7.5 7 6.5 6 5.5 5 4.5 4 3.5 3 2.5 2 1.5 1 0.5 0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
1/3f
f= 1.5

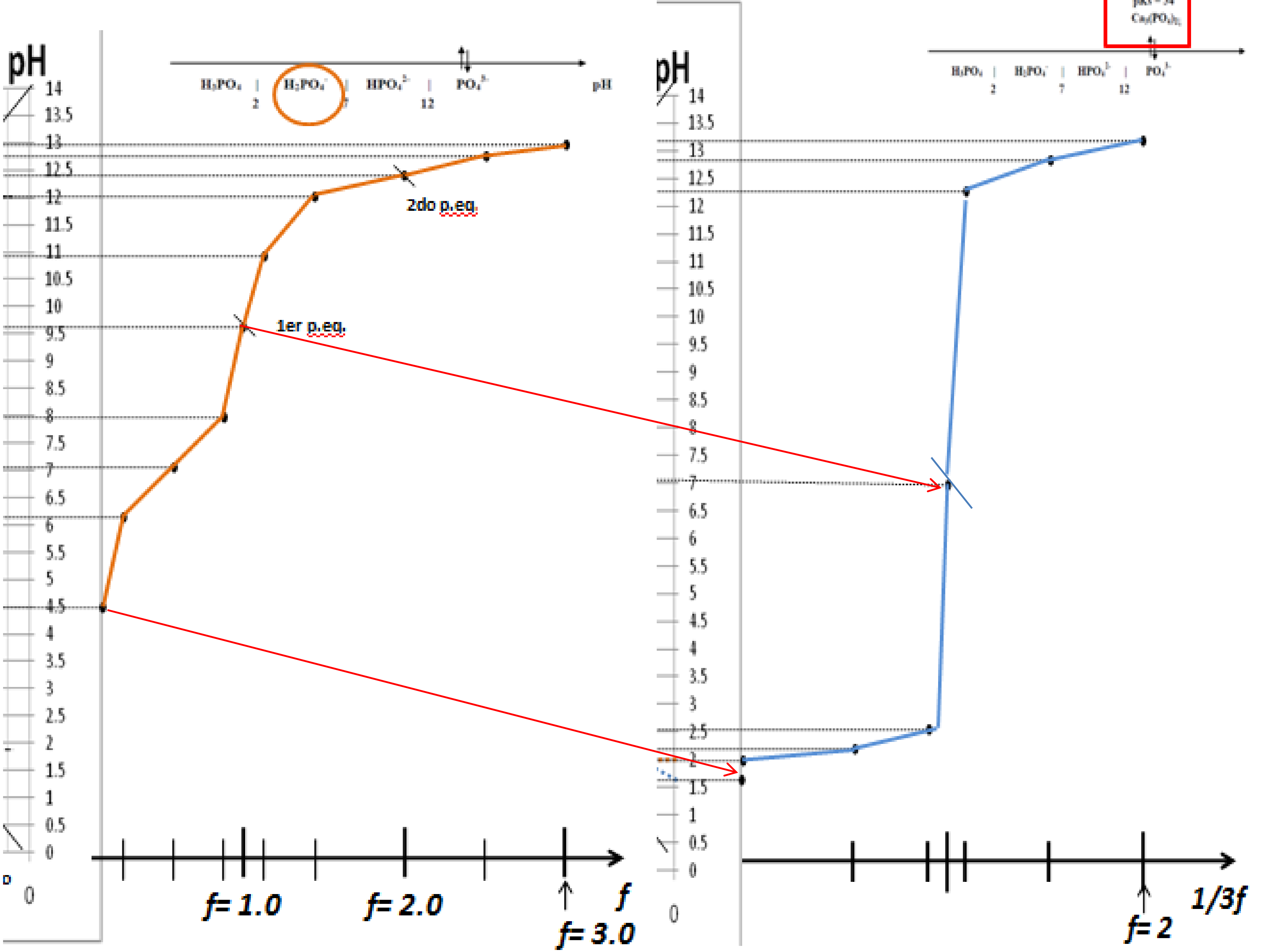


pKs = 34
$Ca_3(PO_4)_2\downarrow$
H_3PO_4 | $H_2PO_4^-$ | HPO_4^{2-} | PO_4^{3-} pH
2 7 12
pH
log[H⁺]
log[$H_2PO_4^-$]
log[H_3PO_4]
log[PO_4^{3-}]
log[HPO_4^{2-}]
log[OH⁻]
log Co
1/3f
f= 2

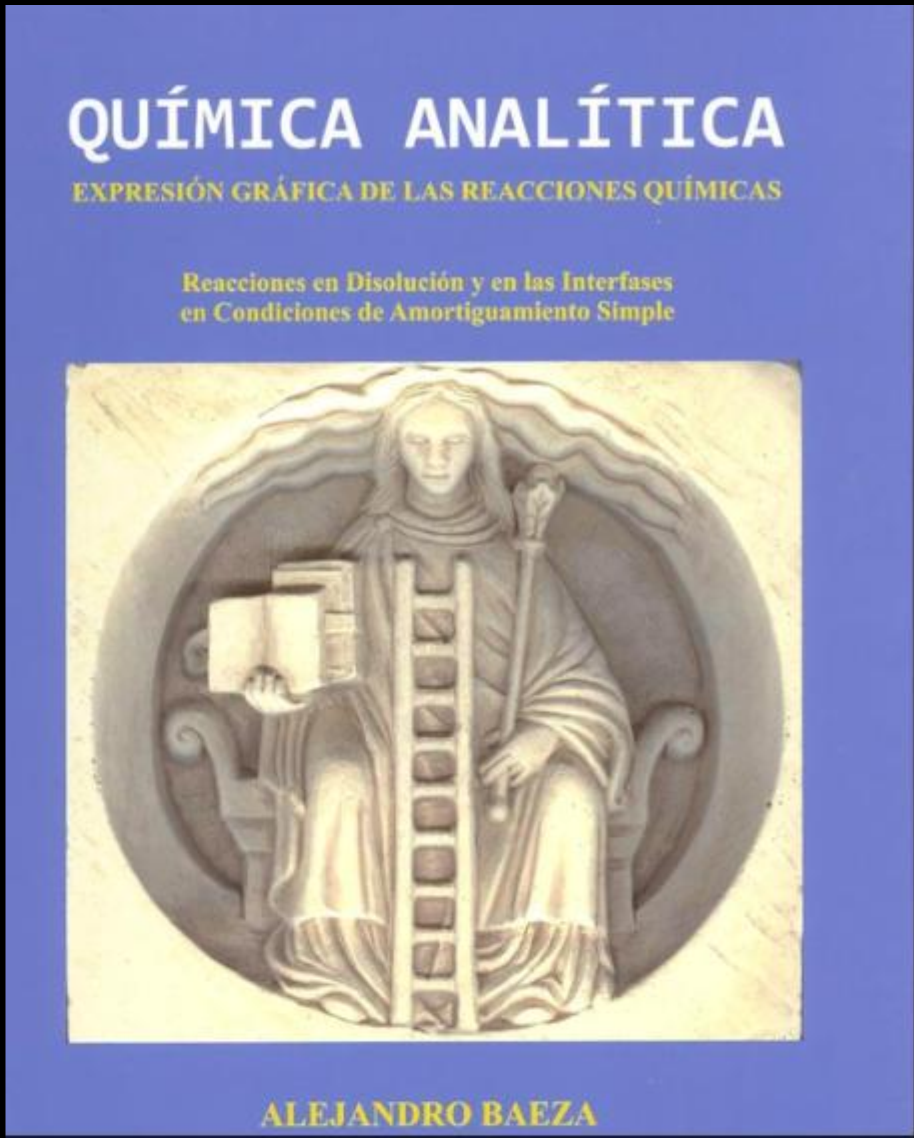

pKs = 34
$Ca_3(PO_4)_2\downarrow$
H_3PO_4 | $H_2PO_4^-$ | HPO_4^{2-} | PO_4^{3-}
2 7 12
pH
log[H⁺]
log[$H_2PO_4^-$]
log[H_3PO_4]
log[PO_4^{3-}]
log[HPO_4^{2-}]
log[OH⁻]
log Co
14 13.5 13 12.5 12 11.5 11 10.5 10 9.5 9 8.5 8 7.5 7 6.5 6 5.5 5 4.5 4 3.5 3 2.5 2 1.5 1 0.5 0
-14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
1/3f
f= 2



pKs = 34
Ca3(PO4)2↓
H3PO4
H2PO4-
HPO42-
PO43-
pH
2
7
12
pH
log[H+]
log[H 2PO4 -]
log[H 3PO4]
log[PO4 3-]
log[HPO4 2-]
log[OH-]
log Co
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-14
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1/3f
f= 2



pH
H3PO4
H2PO4-
HPO4 2-
PO4 3-
pH
2do p.eq.
1er p.eq.
0
f= 1.0
f= 2.0
f= 3.0
f
1/3f
f= 2



http://depa.fquim.unam.mx/amyd

↓

QA I