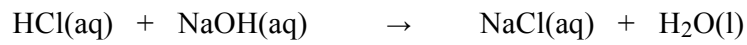
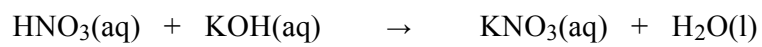
Acids, Bases, pH, and Redox - *Answers at end*

1. If 10.0 mL of 0.100 *M* HCl is titrated with 0.200 *M* NaOH, what volume of sodium hydroxide solution is required to neutralize the acid?



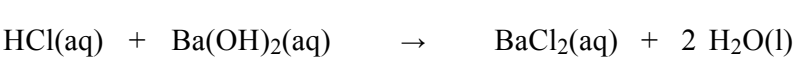
$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

2. If 20.0 mL of 0.500 *M* KOH is titrated with 0.250 *M* HNO_3, what volume of nitric acid is required to neutralize the base?



$$HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(l)$$

3. If 25.0 mL of 0.100 *M* HCl is titrated with 0.150 *M* $Ba(OH)_2$, what volume of barium hydroxide is required to neutralize the acid?

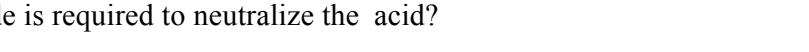


$$2\ HCl(aq) + Ba(OH)_2(aq) \rightarrow BaCl_2(aq) + 2\ H_2O(l)$$

4. If 25.0 mL of 0.100 *M* $Ca(OH)_2$ is titrated with 0.200 *M* HNO_3, what volume of nitric acid is required to neutralize the base?

$$2\ HNO_3(aq) + Ca(OH)_2(aq) \rightarrow 2\ Ca(NO_3)_2(aq) + 2\ H_2O(l)$$

5. If 20.0 mL of 0.200 *M* H_2SO_4 is titrated with 0.100 *M* NaOH, what volume of sodium hydroxide is required to neutralize the acid?

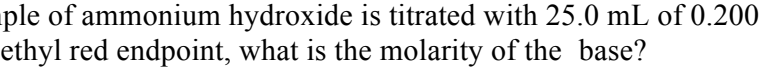


$$H_2SO_4(aq) + 2\ NaOH(aq) \rightarrow Na_2SO_4(aq) + 2\ H_2O(l)$$

6. If 30.0 mL of 0.100 *M* $Ca(OH)_2$ is titrated with 0.150 *M* $HC_2H_3O_2$, what volume of acetic acid is required to neutralize the base?

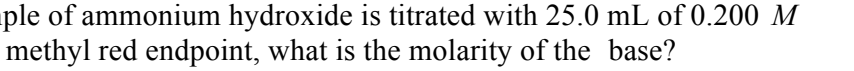
$$2\ HC_2H_3O_2(aq) + Ca(OH)_2(aq) \rightarrow Ca(C_2H_3O_2)_2(aq) + 2\ H_2O(l)$$

7. If a 50.0 mL sample of ammonium hydroxide is titrated with 25.0 mL of 0.200 *M* nitric acid to a methyl red endpoint, what is the molarity of the base?



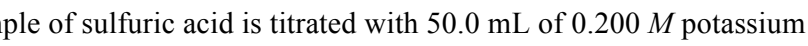
$$NH_4OH(aq) + HNO_3(aq) \rightarrow NH_4NO_3(aq) + H_2O(l)$$

8. If a 50.0 mL sample of ammonium hydroxide is titrated with 25.0 mL of 0.200 *M* sulfuric acid to a methyl red endpoint, what is the molarity of the base?



$$2\ NH_4OH(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq) + 2\ H_2O(l)$$

9. If a 25.0 mL sample of sulfuric acid is titrated with 50.0 mL of 0.200 *M* potassium hydroxide to a phenolphthalein endpoint, what is the molarity of the acid?



$$H_2SO_4(aq) + 2\ KOH(aq) \rightarrow K_2SO_4(aq) + 2\ H_2O(l)$$

10. What is the molarity of a hydrochloric acid solution if 20.00 mL of HCl is required to neutralize 0.424 g of sodium carbonate (105.99 g/mol)?

$$2\ HCl(aq) + Na_2CO_3(aq) \rightarrow 2\ NaCl(aq) + H_2O(l) + CO_2(g)$$

11. What is the molarity of a nitric acid solution if 25.00 mL of HNO_3 is required to neutralize 0.424 g of sodium carbonate (105.99 g/mol)?

$$2\ HNO_3(aq) + Na_2CO_3(aq) \rightarrow 2\ NaNO_3(aq) + H_2O(l) + CO_2(g)$$

12. What is the molarity of a sulfuric acid solution if 30.00 mL of H_2SO_4 is required to neutralize 0.840 g of sodium hydrogen carbonate (84.01 g/mol)?

$$H_2SO_4(aq) + 2\ NaHCO_3(aq) \rightarrow Na_2SO_4(aq) + 2\ H_2O(l) + 2\ CO_2(g)$$

13. What is the molarity of a hydrochloric acid solution if 25.00 mL of HCl is required to neutralize 0.500 g of calcium carbonate (100.09 g/mol)?

$$2\ HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

14. What is the molarity of a sodium hydroxide solution if 40.00 mL of NaOH is required to neutralize 0.900 g of oxalic acid, $H_2C_2O_4$, (90.04 g/mol)?

$$H_2C_2O_4(aq) + 2\ NaOH(aq) \rightarrow Na_2C_2O_4(aq) + 2\ H_2O(l)$$

15. What is the molarity of a sodium hydroxide solution if 35.00 mL of NaOH is required to neutralize 1.555 g of KHP, that is $KHC_8H_4O_4$ (204.23 g/mol)?

$$KHC_8H_4O_4(aq) + NaOH(aq) \rightarrow KNaC_8H_4O_4(aq) + H_2O(l)$$

16. If a 0.200 g sample of sodium hydroxide (40.00 g/mol) is completely neutralized with 0.100 *M* H_2SO_4, what volume of sulfuric acid is required?

$$H_2SO_4(aq) + 2\ NaOH(aq) \rightarrow Na_2SO_4(aq) + 2\ H_2O(l)$$

17. If 0.900 g of oxalic acid, $H_2C_2O_4$, (90.04 g/mol) is completely neutralized with 0.300 *M* NaOH, what volume of sodium hydroxide is required?

$$H_2C_2O_4(aq) + 2\ NaOH(aq) \rightarrow Na_2C_2O_4(aq) + 2\ H_2O(l)$$

18. If 1.020 g of $KHC_8H_4O_4$ (204.23 g/mol) is completely neutralized with 0.200 *M* $Ba(OH)_2$, what volume of barium hydroxide is required?

$$2\ KHC_8H_4O_4(aq) + Ba(OH)_2(aq) \rightarrow BaK_2(C_8H_4O_4)_2(aq) + 2\ H_2O(l)$$

19. Glycine is an amino acid that can be abbreviated HGly. If 27.50 mL of 0.120 *M* NaOH neutralizes 0.248 g of HGly, what is the molar mass of the amino acid?

$$HGly(aq) + NaOH(aq) \rightarrow NaGly(aq) + H_2O(l)$$

20. Proline is an amino acid that can be abbreviated HPro. If 33.55 mL of 0.150 *M* NaOH neutralizes 0.579 g of HPro, what is the molar mass of the amino acid?

$$HPro(aq) + NaOH(aq) \rightarrow NaPro(aq) + H_2O(l)$$

21. Lactic acid is found in sour milk and can be abbreviated HLac. If 47.50 mL of 0.275 *M* NaOH neutralizes 1.180 g of HLac, what is the molar mass of the acid?

$$HLac(aq) + NaOH(aq) \rightarrow NaLac(aq) + H_2O(l)$$

22. What is the pH of an aqueous solution if the $[H^+] = 5.5 \times 10^{-3}$ *M*?

23. What is the pH of an aqueous solution if the $[H^+] = 4.2 \times 10^{-5}$ *M*?

24. What is the pH of an aqueous solution if the $[H^+] = 7/5 \times 10^{-8}$ *M*?

25. What is the $[H^+]$ in an acid rain sample that has a pH = 3.22?

26. What is the $[H^+]$ in a blood sample that has a pH = 7.30?

27. What is the $[H^+]$ in a bleach sample that has a pH = 9.55?

28. What is the $[OH^-]$ in a seawater sample that has a pH = 8.65?

29. What is the $[OH^-]$ in an ammonia solution that has a pH = 10.20?

30. What is the $[OH^-]$ in an oven-cleaning solution that has a pH = 12.35?

31. What substance is oxidized in the following redox reaction?

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

32. What substance is reduced in the following redox reaction?

$$Co(s) + 2\ HCl(aq) \rightarrow CoCl_2(aq) + H_2(g)$$

33. What substance is oxidized in the following redox reaction?

$$F_2(g) + 2\ Br^-(aq) \rightarrow 2\ F^-(aq) + Br_2(l)$$

34. What substance is oxidized in the following redox reaction?

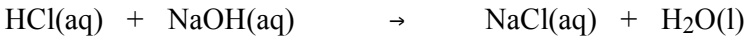
$$HgCl_2(aq) + Sn^{2+}(aq) \rightarrow Sn^{4+}(aq) + Hg_2Cl_2(s) + Cl^-(aq)$$

35. What substance is reduced in the following redox reaction?

$$H^+(aq) + Fe(s) + NO_3^-(aq) \rightarrow Fe^{3+}(aq) + NO(aq) + H_2O(l)$$

Acids, Bases, pH, and Redox - *Answers*

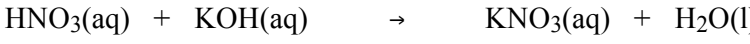
1. If 10.0 mL of 0.100 *M* HCl is titrated with 0.200 *M* NaOH, what volume of sodium hydroxide solution is required to neutralize the acid?



$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

$M_1V_1 = M_2V_2$ (0.100M) (0.010L) = (0.200M)(V_2) V_2 = 0.005 L = **5 mL**

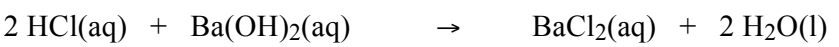
2. If 20.0 mL of 0.500 *M* KOH is titrated with 0.250 *M* HNO_3, what volume of nitric acid is required to neutralize the base?



$HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(l)$

$M_1V_1 = M_2V_2$ (0.500M) (0.020L) = (0.250M)(V_2) V_2 = 0.040 L = **40 mL**

3. If 25.0 mL of 0.100 *M* HCl is titrated with 0.150 *M* $Ba(OH)_2$, what volume of barium hydroxide is required to neutralize the acid?

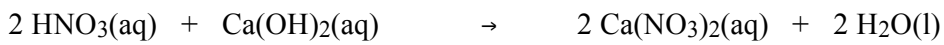


$2\ HCl(aq) + Ba(OH)_2(aq) \rightarrow BaCl_2(aq) + 2\ H_2O(l)$

$M_1V_1 = M_2V_2$ (0.100M) (0.025L) = (0.150M)(V_2) V_2 = 0.0166 L = 16.6 mL OH^-

But there are 2 OH's per $Ba(OH)_2$ so it takes half this volume = **8.33 mL of $Ba(OH)_2$**

4. If 25.0 mL of 0.100 *M* $Ca(OH)_2$ is titrated with 0.200 *M* HNO_3, what volume of nitric acid is required to neutralize the base?

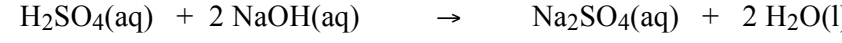


$2\ HNO_3(aq) + Ca(OH)_2(aq) \rightarrow 2\ Ca(NO_3)_2(aq) + 2\ H_2O(l)$

$M_1V_1 = M_2V_2$ (0.100M) (0.025L) = (0.200M)(V_2) V_2 = 0.0125 L = 12.5 mL H+

But it takes 2 HNO_3's per $Ca(OH)_2$ so it takes twice this volume = **25 mL of HNO_3**

5. If 20.0 mL of 0.200 *M* H_2SO_4 is titrated with 0.100 *M* NaOH, what volume of sodium hydroxide is required to neutralize the acid?



$H_2SO_4(aq) + 2\ NaOH(aq) \rightarrow Na_2SO_4(aq) + 2\ H_2O(l)$

0.200 M H_2SO_4 = 0.400 M H^+

$M_1V_1 = M_2V_2$ (0.40M) (0.020L) = (0.100M)(V_2) V_2 = 0.080 L = **80 mL NaOH**

6. If 30.0 mL of 0.100 *M* $Ca(OH)_2$ is titrated with 0.150 *M* $HC_2H_3O_2$, what volume of acetic acid is required to neutralize the base?

$$2\ HC_2H_3O_2(aq) + Ca(OH)_2(aq) \rightarrow Ca(C_2H_3O_2)_2(aq) + 2\ H_2O(l)$$

0.100 M $Ca(OH)_2$ = 0.200 M OH^-

$M_1V_1 = M_2V_2$ (0.200M) (0.030L) = (0.150M)(V_2) V_2 = 0.040 L = **40 mL NaOH**

7. If a 50.0 mL sample of ammonium hydroxide is titrated with 25.0 mL of 0.200 *M* nitric acid to a methyl red endpoint, what is the molarity of the base?

$$NH_4OH(aq) + HNO_3(aq) \rightarrow NH_4NO_3(aq) + H_2O(l)$$

$M_1V_1 = M_2V_2$ (0.200M) (0.025L) = (M_2)(0.050L) M_2 = 0.100 M NH_4OH

8. If a 50.0 mL sample of ammonium hydroxide is titrated with 25.0 mL of 0.200 *M* sulfuric acid to a methyl red endpoint, what is the molarity of the base?

$$2\ NH_4OH(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq) + 2\ H_2O(l)$$

0.200 M H_2SO_4 = 0.400 M H^+

$M_1V_1 = M_2V_2$ (0.400M) (0.025L) = (M_2)(0.050L) M_2 = **0.200 M NH_4OH**

9. If a 25.0 mL sample of sulfuric acid is titrated with 50.0 mL of 0.200 *M* potassium hydroxide to a phenolphthalein endpoint, what is the molarity of the acid?

$$H_2SO_4(aq) + 2\ KOH(aq) \rightarrow K_2SO_4(aq) + 2\ H_2O(l)$$

$M_1V_1 = M_2V_2$ (0.200M) (0.050L) = (M_2)(0.025L) M_2 = 0.400 M H^+

But, there are 2 H's per H_2SO_4 so [H_2SO_4] = **0.200M**

10. What is the molarity of a hydrochloric acid solution if 20.00 mL of HCl is required to neutralize 0.424 g of sodium carbonate (105.99 g/mol)?

$$2\ HCl(aq) + Na_2CO_3(aq) \rightarrow 2\ NaCl(aq) + H_2O(l) + CO_2(g)$$

0.424 g/105.99 g/mol = 0.0040 mol Na_2CO_3

Each Na_2CO_3 requires 2 HCl so we need 0.0080 mol HCl

MV = moles (M)(0.020L) = 0.0080 mole HCl M = **0.40 M HCl**

11. What is the molarity of a nitric acid solution if 25.00 mL of HNO_3 is required to neutralize 0.424 g of sodium carbonate (105.99 g/mol)?

$$2\ HNO_3(aq) + Na_2CO_3(aq) \rightarrow 2\ NaNO_3(aq) + H_2O(l) + CO_2(g)$$

0.424 g/105.99 g/mol = 0.0040 mol Na_2CO_3

Each Na_2CO_3 requires 2 HNO_3 so we need 0.0080 mol HNO_3

MV = moles (M)(0.025L) = 0.0080 mole HNO_3 M = **0.32 M HNO_3**

12. What is the molarity of a sulfuric acid solution if 30.00 mL of H_2SO_4 is required to neutralize 0.840 g of sodium hydrogen carbonate (84.01 g/mol)?

$$H_2SO_4(aq) + 2\ NaHCO_3(aq) \rightarrow Na_2SO_4(aq) + 2\ H_2O(l) + 2\ CO_2(g)$$

0.840 g / 84.01 g/mol = 0.010 mol $NaHCO_3$

It takes 2 NaHCO3 per H_2SO_4 so you need 0.005 mol H_2SO_4

MV = moles M(0.030L) = 0.005 moles M = **0.167 M H_2SO_4**

13. What is the molarity of a hydrochloric acid solution if 25.00 mL of HCl is required to neutralize 0.500 g of calcium carbonate (100.09 g/mol)?

$$2\ HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

0.500 g/100.09 g/mol = 0.005 mol $CaCO_3$

Each mole of CaCO3 requires 2 mol HCl so you need 0.005 x 2 = 0.010 mol HCl

MV = moles M(0.025L) = 0.010 mol M = **0.40 M HCl**

14. What is the molarity of a sodium hydroxide solution if 40.00 mL of NaOH is required to neutralize 0.900 g of oxalic acid, $H_2C_2O_4$, (90.04 g/mol)?

$$H_2C_2O_4(aq) + 2\ NaOH(aq) \rightarrow Na_2C_2O_4(aq) + 2\ H_2O(l)$$

0.900 g / 90.04 g/mol = 0.010 mol Oxalic acid

It takes 2 mole NaOH for every mole of Oxalic acid

so you need 2 x 0.010 mol = 0.02 mol NaOH

MV = moles M(0.040L) = 0.020 mole NaOH **M = 0.50 M NaOH**

15. What is the molarity of a sodium hydroxide solution if 35.00 mL of NaOH is required to neutralize 1.555 g of KHP, that is $KHC_8H_4O_4$ (204.23 g/mol)?

$$KHC_8H_4O_4(aq) + NaOH(aq) \rightarrow KNaC_8H_4O_4(aq) + H_2O(l)$$

1.555g / 204.23 g/mol = 0.00761 mol KHP

1 mole KHP needs 1 mole of NaOH so, 0.00761 mole KHP = 0.00761 mole NaOH 0.00761

mole NaOH / 0.0351 L = **0.2175 M NaOH**

16. If a 0.200 g sample of sodium hydroxide (40.00 g/mol) is completely neutralized with 0.100 *M* H_2SO_4, what volume of sulfuric acid is required?

$$H_2SO_4(aq) + 2\ NaOH(aq) \rightarrow Na_2SO_4(aq) + 2\ H_2O(l)$$

0.200 g NaOH / 40 g/mol = 0.005 mol NaOH

1 mole of H_2SO_4 needs 2 mole NaOH so 0.005 mole NaOH needs 0.0025 mole H_2SO_4

MV = moles (0.100 M H_2SO_4) (V) = 0.0025 mole V = 0.0250 L = **25 mL**

17. If 0.900 g of oxalic acid, $H_2C_2O_4$, (90.04 g/mol) is completely neutralized with 0.300 *M* NaOH, what volume of sodium hydroxide is required? $H_2C_2O_4(aq)$

$$+ 2\ NaOH(aq) \rightarrow Na_2C_2O_4(aq) + 2\ H_2O(l)$$

0.900 g / 90.04 g/mol = 0.010 mol Oxalic acid

It takes 2 mole NaOH for every mole of Oxalic acid

so you need 2 x 0.010 mol = 0.02 mol NaOH

MV = moles (0.300M) (V) = 0.020 mole NaOH V = 0.0666 L = **66.6 mL**

18. If 1.020 g of $KHC_8H_4O_4$ (204.23 g/mol) is completely neutralized with 0.200 *M* $Ba(OH)_2$, what volume of barium hydroxide is required?

$$2\ KHC_8H_4O_4(aq) + Ba(OH)_2(aq) \rightarrow BaK_2(C_8H_4O_4)_2(aq) + 2\ H_2O(l)$$

1.020g / 204.23 g/mol = 0.0050 mol KHP

2 mole KHP needs 1 mole of $Ba(OH)_2$ so, 0.0050 mole KHP needs 0.0025 mole $Ba(OH)_2$

MV = moles (0.200 M) (V) = 0.0025 mole $Ba(OH)_2$ V = 0.01250 L = **12.5 mL**

19. Glycine is an amino acid that can be abbreviated HGly. If 27.50 mL of 0.120 *M* NaOH neutralizes 0.248 g of HGly, what is the molar mass of the amino acid?

$$HGly(aq) + NaOH(aq) \rightarrow NaGly(aq) + H_2O(l)$$

MV = moles (0.120 M) (0.02750L) = 0.033 mole NaOH = 0.0033 mole HGly

0.248 g / 0.0033 mole HGly = 75.12 g/mol HGly

20. Proline is an amino acid that can be abbreviated HPro. If 33.55 mL of 0.150 *M* NaOH neutralizes 0.579 g of HPro, what is the molar mass of the amino acid?

$$HPro(aq) + NaOH(aq) \rightarrow NaPro(aq) + H_2O(l)$$

MV = moles (0.150 M) (0.03355L) = 0.005033 mole NaOH = 0.005033 mole HPro

0.579 g / 0.050033 mole HPro = **115.05 g/mol HPro**

21. Lactic acid is found in sour milk and can be abbreviated HLac. If 47.50 mL of 0.275
M NaOH neutralizes 1.180 g of HLac, what is the molar mass of the acid?

$$HLac(aq) + NaOH(aq) \rightarrow NaLac(aq) + H_2O(l)$$

MV = moles (0.275 M) (0.0475L) = 0.01306 mole NaOH = 0.01306 mole HLac

1.180 g / 0.01306 mole HLac = **90.33 g/mol HLac**

22. What is the pH of an aqueous solution if the $[H^+] = 5.5x10^{-3}$

M? pH = - log $[H^+]$ pH = - log $[5.5x10^{-3}]$ = **2.26**

23. What is the pH of an aqueous solution if the $[H^+] = 4.2x10^{-5}$

M? pH = - log $[H^+]$ pH = - log $[4.2x10^{-5}]$ = **4.38**

24. What is the pH of an aqueous solution if the $[H^+] = 7.5x10^{-8}$

M? pH = - log $[H^+]$ pH = - log $[7.5x10^{-8}]$ = **7.12**

25. What is the [H+] in a blood sample that has a pH = 3.22?
$[H+] = 10^{-pH}$ $[H+] = 10^{-3.22}$ $[H+] =$ **$6.03x10^{-4}$ M**

26. What is the [H+] in a blood sample that has a pH = 7.30?
$[H+] = 10^{-pH}$ $[H+] = 10^{-7.30}$ $[H+] =$ **$5.01x10^{-8}$ M**

25. What is the [H^+] in a bleach sample that has a pH = 9.55?

$[H+] = 10^{-pH}$ $[H+] = 10^{-9.55}$ $[H+] = \mathbf{2.82x10^{-10}\ M}$

26. What is the [OH^-] in a seawater sample that has a pH = 8.65?

$[H+] = 10^{-pH}$ $[H+] = 10^{-8.65}$ $[H+] = 2.24x10^{-9}$ M

$[H+]\,[OH-] = 1x10^{-14}$ $[2.24x10^{-9}\ M]\,[OH-] = 1x10^{-14}$ $[OH-] = \mathbf{4.46x10^{-9}\ M}$

27. What is the [OH^-] in an ammonia solution that has a pH = 10.20?

$[H+] = 10^{-pH}$ $[H+] = 10^{-10.20}$ $[H+] = 6.31x10^{-11}$ M

$[H+]\,[OH-] = 1x10^{-14}$ $[6.31x10^{-11}\ M]\,[OH-] = 1x10^{-14}$ $[OH-] = \mathbf{1.58x10^{-4}\ M}$

28. What is the [OH^-] in an oven-cleaning solution that has a pH = 12.35?

$[H+] = 10^{-pH}$ $[H+] = 10^{-12.35}$ $[H+] = 4.47x10^{-13}$ M

$[H+]\,[OH-] = 1x10^{-14}$ $[4.47x10^{-13}\ M]\,[OH-] = 1x10^{-14}$ $[OH-] = \mathbf{0.0224\ M}$

29. What substance is oxidized in the following redox reaction?

$\underline{\boldsymbol{Zn(s)}} + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$

30. What substance is reduced in the following redox reaction? $Co(s) + 2\,\underline{\boldsymbol{H}}Cl(aq) \rightarrow CoCl_2(aq) + H_2(g)$

31. What substance is oxidized in the following redox reaction?

$F_2(g) + 2\,\underline{\boldsymbol{Br^-}}(aq) \rightarrow 2\,F^-(aq) + Br_2(l)$

32. What substance is oxidized in the following redox reaction?

$HgCl_2(aq) + \underline{\boldsymbol{Sn^{2+}}}(aq) \rightarrow Sn^{4+}(aq) + Hg_2Cl_2(s) + Cl^-(aq)$

33. What substance is reduced in the following redox reaction?

$H^+(aq) + Fe(s) + \underline{\boldsymbol{N}}O_3^-(aq) \rightarrow Fe^{3+}(aq) + NO(aq) + H_2O(l)$