

Acids, Bases & pH Calculations

Key formulas

$\text{pH} = -\log[\text{H}_3\text{O}^+]$ · $\text{pOH} = -\log[\text{OH}^-]$ · $\text{pH} + \text{pOH} = 14.00$ (at 25 °C) · $[\text{H}_3\text{O}^+] = 10^{-\text{pH}}$

Scale: pH < 7 acidic, = 7 neutral, > 7 basic. Each unit is a factor of 10.

Strong acids (ionize completely): HCl, HBr, HI, HNO₃, H₂SO₄, HClO₄ · **Strong bases:** Group 1 hydroxides, Ca(OH)₂, Ba(OH)₂ (two OH⁻ each)

Sig figs: the number of decimal places in pH = the number of significant figures in the concentration.

A Acidic, basic or neutral?

4 marks

1. pH = 3.2 _____
2. pH = 7.00 _____
3. pH = 11.5 _____
4. $[\text{H}_3\text{O}^+] = 1.0 \times 10^{-9} \text{ mol/L}$ _____

B Arrhenius acid or base?

4 marks

State acid or base, and which ion it releases in water.

- | | |
|---------------------------|------------------------------|
| 5. HCl _____ | 6. NaOH _____ |
| 7. HNO ₃ _____ | 8. Ca(OH) ₂ _____ |

C pH from $[\text{H}_3\text{O}^+]$

4 marks

9. Find the pH of a solution with $[\text{H}_3\text{O}^+] = 1.0 \times 10^{-3} \text{ mol/L}$.

10. Find the pH of a solution with $[\text{H}_3\text{O}^+] = 2.5 \times 10^{-4} \text{ mol/L}$.

11. Find the pH of 0.010 mol/L HCl.

12. Find the pH of 0.0050 mol/L HNO₃.

D $[\text{H}_3\text{O}^+]$ from pH

3 marks

13. Find $[\text{H}_3\text{O}^+]$ for a solution with pH = 4.00.

14. Find $[\text{H}_3\text{O}^+]$ for a solution with pH = 2.70.

15. Find $[\text{H}_3\text{O}^+]$ for a solution with $\text{pH} = 9.40$.

E Bases: pOH and pH

4 marks

16. Find the pOH and pH of 0.010 mol/L NaOH.

17. Find the pOH and pH of 0.0025 mol/L KOH.

18. Find the pOH and pH of 0.050 mol/L $\text{Ba}(\text{OH})_2$.

19. A solution has $\text{pH} = 10.50$. Find its pOH and $[\text{OH}^-]$.

F Dilution and the pH scale

2 marks

20. 10.0 mL of 0.10 mol/L HCl is diluted to 1.00 L. What is the new pH?

21. How many times more acidic is a solution with pH 3 than one with pH 5?

G Neutralization

4 marks

2 marks each.

22. $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$. What volume of 0.20 mol/L NaOH is needed to neutralize 30.0 mL of 0.10 mol/L HCl?

23. $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$. What volume of 0.100 mol/L NaOH neutralizes 20.0 mL of 0.050 mol/L H_2SO_4 ?

H Spot the mistake

2 marks

24. A student calculates the pH of 0.050 mol/L $\text{Ba}(\text{OH})_2$ as 12.70. Explain the error and correct it.

25. A student says a solution with pH 2 is twice as acidic as one with pH 4. Explain the error and correct it.

Acids, Bases & pH Calculations**ANSWER KEY****Key formulas**

$$\text{pH} = -\log[\text{H}_3\text{O}^+] \quad \text{pOH} = -\log[\text{OH}^-] \quad \text{pH} + \text{pOH} = 14.00 \text{ (at } 25^\circ\text{C)} \quad [\text{H}_3\text{O}^+] = 10^{-\text{pH}}$$

Scale: pH < 7 acidic, = 7 neutral, > 7 basic. Each unit is a factor of 10.

Strong acids (ionize completely): HCl, HBr, HI, HNO₃, H₂SO₄, HClO₄ · **Strong bases:** Group 1 hydroxides, Ca(OH)₂, Ba(OH)₂ (two OH⁻ each)

Sig figs: the number of decimal places in pH = the number of significant figures in the concentration.

A Acidic, basic or neutral?

4 marks

- | | |
|--|-------------------|
| 1. pH = 3.2 | Acidic |
| 2. pH = 7.00 | Neutral |
| 3. pH = 11.5 | Basic |
| 4. $[\text{H}_3\text{O}^+] = 1.0 \times 10^{-9} \text{ mol/L}$ | Basic (pH = 9.00) |

B Arrhenius acid or base?

4 marks

State acid or base, and which ion it releases in water.

- | | | | |
|---------------------|--|------------------------|----------------------------------|
| 5. HCl | Acid: releases H ⁺ in water | 6. NaOH | Base: releases OH ⁻ |
| 7. HNO ₃ | Acid: releases H ⁺ | 8. Ca(OH) ₂ | Base: releases 2 OH ⁻ |

C pH from [H₃O⁺]

4 marks

9. Find the pH of a solution with $[\text{H}_3\text{O}^+] = 1.0 \times 10^{-3} \text{ mol/L}$.
 $\text{pH} = -\log(1.0 \times 10^{-3}) = 3.00$
10. Find the pH of a solution with $[\text{H}_3\text{O}^+] = 2.5 \times 10^{-4} \text{ mol/L}$.
 $\text{pH} = -\log(2.5 \times 10^{-4}) = 3.60$
11. Find the pH of 0.010 mol/L HCl.
 $\text{pH} = -\log(0.010) = 2.00$
12. Find the pH of 0.0050 mol/L HNO₃.
 $\text{pH} = -\log(5.0 \times 10^{-3}) = 2.30$

D [H₃O⁺] from pH

3 marks

13. Find $[\text{H}_3\text{O}^+]$ for a solution with pH = 4.00.
 $[\text{H}_3\text{O}^+] = 10^{-4.00} = 1.0 \times 10^{-4} \text{ mol/L}$
14. Find $[\text{H}_3\text{O}^+]$ for a solution with pH = 2.70.
 $[\text{H}_3\text{O}^+] = 10^{-2.70} = 2.0 \times 10^{-3} \text{ mol/L}$
15. Find $[\text{H}_3\text{O}^+]$ for a solution with pH = 9.40.
 $[\text{H}_3\text{O}^+] = 10^{-9.40} = 4.0 \times 10^{-10} \text{ mol/L}$

E Bases: pOH and pH

4 marks

16. Find the pOH and pH of 0.010 mol/L NaOH.
 $\text{pOH} = -\log(0.010) = 2.00$; $\text{pH} = 14.00 - 2.00 = 12.00$
17. Find the pOH and pH of 0.0025 mol/L KOH.
 $\text{pOH} = -\log(0.0025) = 2.60$; $\text{pH} = 14.00 - 2.60 = 11.40$
18. Find the pOH and pH of 0.050 mol/L $\text{Ba}(\text{OH})_2$.
 $\text{pOH} = -\log(0.10)$ ($[\text{OH}^-] = 2 \times 0.050 = 0.10 \text{ mol/L}$) $= 1.00$; $\text{pH} = 14.00 - 1.00 = 13.00$
19. A solution has $\text{pH} = 10.50$. Find its pOH and $[\text{OH}^-]$.
 $\text{pOH} = 14.00 - 10.50 = 3.50$; $[\text{OH}^-] = 10^{-3.50} = 3.2 \times 10^{-4} \text{ mol/L}$

F Dilution and the pH scale

2 marks

20. 10.0 mL of 0.10 mol/L HCl is diluted to 1.00 L. What is the new pH?
 $c = (0.10 \times 10.0) \div 1000 = 1.0 \times 10^{-3} \text{ mol/L}$; $\text{pH} = 3.00$
21. How many times more acidic is a solution with pH 3 than one with pH 5?
Each pH unit is a factor of 10: $10^{(5-3)} = 100$ times more acidic.

G Neutralization

4 marks

2 marks each.

22. $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$. What volume of 0.20 mol/L NaOH is needed to neutralize 30.0 mL of 0.10 mol/L HCl?
 $n(\text{HCl}) = 0.10 \times 0.0300 = 0.0030 \text{ mol} = n(\text{NaOH})$; $V = 0.0030 \div 0.20 = 0.015 \text{ L} = 15.0 \text{ mL}$
23. $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$. What volume of 0.100 mol/L NaOH neutralizes 20.0 mL of 0.050 mol/L H_2SO_4 ?
 $n(\text{H}_2\text{SO}_4) = 0.050 \times 0.0200 = 0.0010 \text{ mol}$; $n(\text{NaOH}) = 2 \times 0.0010 = 0.0020 \text{ mol}$; $V = 0.0020 \div 0.100 = 20.0 \text{ mL}$

H Spot the mistake

2 marks

24. A student calculates the pH of 0.050 mol/L $\text{Ba}(\text{OH})_2$ as 12.70. Explain the error and correct it.
 $\text{Ba}(\text{OH})_2$ releases 2 OH^- , so $[\text{OH}^-] = 0.10 \text{ mol/L}$, $\text{pOH} = 1.00$ and $\text{pH} = 13.00$.
25. A student says a solution with pH 2 is twice as acidic as one with pH 4. Explain the error and correct it.
pH is logarithmic: a difference of 2 units is $10^2 = 100$ times more acidic.