

Chemistry

Student Solutions Manual



10th Edition

Whitten | Davis | Peck | Stanley

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TENTH EDITION

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Foreword to the Students

This Solutions Manual supplements the textbook, *General Chemistry*, tenth edition, by Kenneth W. Whitten, Raymond E. Davis, M. Larry Peck and George Stanley. The solutions of the 1441 even-numbered problems at the end of the chapters have been worked out in a detailed, step-by-step fashion.

Your learning of chemistry serves two purposes: (1) to accumulate fundamental knowledge in chemistry which you will use to understand the world around you, and (2) to enhance your ability to make logical deductions in science. This ability comes when you know how to reason in a scientific way and how to perform the mathematical manipulations necessary for solving certain problems. The excellent textbook by Whitten, Davis, Peck and Stanley provides you with a wealth of chemical knowledge, accompanied by good solid examples of logical scientific deductive reasoning. The problems at the end of the chapters are a review, a practice and, in some cases, a challenge to your scientific problem-solving abilities. It is the fundamental spirit of this Solutions Manual to help you to understand the scientific deductive process involved in each problem.

In this manual, I provide you with a solution and an answer to the numerical problems, but the emphasis lies on providing the step-by-step reasoning behind the mathematical manipulations. In some cases, I present as many as three different approaches to solve the same problem, since we understand that each of you has your own unique learning style. In stoichiometry as well as in many other types of calculations, the "unit factor" method is universally emphasized in general chemistry textbooks. I think that the over-emphasis of this method may train you to regard chemistry problems as being simply mathematical manipulations in which the only objective is to cancel units and get the answer. My goal is for you to understand the principles behind the calculations and hopefully to visualize with your mind's eye the chemical processes and the experimental techniques occurring as the problem is being worked out on paper. And so I have dissected the "unit factor" method for you and introduced chemical meaning into each of the steps.

I gratefully acknowledge the tremendous help over the years provided by Frank Kolar in the preparation of this manuscript.

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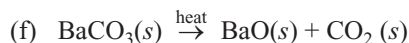
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6-106. Refer to Section 6-7.

The decomposition reactions can be identified easily as one compound breaking down, i.e., decomposing, to other compounds, elements or a combination of element(s) and compound(s). There is only one: (f).

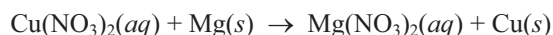


6-108. Refer to Sections 6-5 and 6-10.

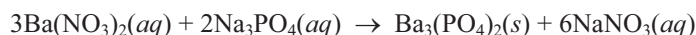
- (a) The oxidation-reduction reactions that form gaseous products are (e), (g), (i), (m) and (o).
- (b) The redox reactions that also fit the definition of gas-formation reactions because they do not have any gaseous reactants are only (i) and (o).

6-110. Refer to Sections as stated.

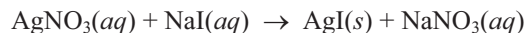
- (a) Copper metal is formed by a displacement reaction. (Refer to Section 6-8 and Table 6-9.)



- (b) Solid barium phosphate is formed in a precipitation reaction.
(Refer to Sections 6-1, 6-9, and the Solubility Guidelines given in Table 6-4.)



- (c) There is no reaction because Al is a less active metal than Ca.
(Refer to Section 6-8 and Table 6-9.)
- (d) Solid silver iodide is formed in a precipitation reaction.
(Refer to Sections 6-1, 6-9, and the Solubility Guidelines given in Table 6-4.)



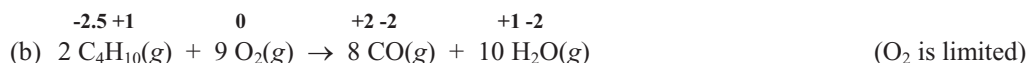
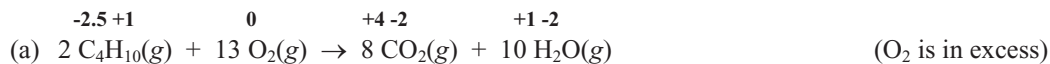
6-112. Refer to Sections as stated.

- (a) Both 1.2 M CH_3COOH and 0.12 M CH_3COOH are equally weak acids, only their concentrations are different (Section 6-1). In fact, the more dilute CH_3COOH solution actually ionizes a little more into its ions (Chapter 18).
- (b) The salt produced when nitric acid, HNO_3 , reacts with potassium hydroxide, KOH , is KNO_3 , not KNO_4 (Section 6-9).
- (c) The first two statements are correct - nickel reacts with HCl and not steam, but magnesium is active enough to react with steam. Therefore magnesium is more reactive than nickel (Section 6-8).

6-114. Refer to Section 6-11 and Table 6-10.

Displacement reactions are always oxidation-reduction reactions, while metathesis reactions are never redox reactions.

6-116. Refer to Section 6-5.



13-28. Refer to Section 13-4 and Figure 13-8.

Surface tension is a measure of the inward intermolecular forces of attraction among liquid particles that must be overcome to expand the surface area. A measurable tension in the surface of the liquid is caused by an imbalance set up between the intermolecular forces operating at the surface and those operating within the liquid. As the temperature increases, the increased kinetic energy and greater movement of the particles in the liquid tend to counteract the intermolecular forces, resulting in the lowering of surface tension.

13-30. Refer to Sections 13-3, 13-4, 13-6 and 13-7, and Table 13-6.

There are similarities between the intermolecular attractions used to describe on a molecular level (1) viscosity, (2) surface tension, (3) the rate of evaporation and resulting vapor pressure of a liquid. For compounds in the liquid phase that have *strong* intermolecular forces of attraction operating between its molecules:

- (1) the molecules cannot slide easily past each other, and the liquid has a *high* viscosity;
- (2) the molecules at the surface of a liquid have an extra strong attraction for each other, and the liquid has a *high* surface tension, and
- (3) the molecules are attracted strongly to each other in the liquid phase and do not evaporate as easily, effecting a *low* rate of evaporation and a *low* vapor pressure.

13-32. Refer to Sections 13-2 and 13-7, and Table 13-3.

The weaker the intermolecular forces between molecules in the liquid phase, the higher is the vapor pressure. Generally, hydrogen bonding and the cumulative dispersion forces in larger molecules are the most significant factors (see Table 13-3). In order of decreasing vapor pressure,

- | | |
|--|---|
| (a) $\text{BiCl}_3 > \text{BiBr}_3$ | BiCl_3 is smaller than BiBr_3 , has weaker dispersion forces and thus has a higher vapor pressure at the same temperature. |
| (b) $\text{CO} > \text{CO}_2$ | CO is smaller, has weaker dispersion forces and a higher vapor pressure than CO_2 . Note from Table 13-3 that even though CO is polar, its dipole moment is extremely low and its dipole-dipole interaction energy is nearly zero. |
| (c) $\text{N}_2 > \text{NO}$ | Both are small molecules of comparable size, and therefore have comparable dispersion forces. NO however is polar and has permanent dipole-dipole interactions, whereas N_2 is nonpolar and has only dispersion forces. Therefore N_2 has the higher vapor pressure. |
| (d) $\text{HCOOCH}_3 > \text{CH}_3\text{COOH}$ | Methyl formate (HCOOCH_3) and acetic acid (CH_3COOH) have the same molecular formula, $\text{C}_2\text{H}_4\text{O}_2$, and are about the same size, so both have similar dispersion forces. CH_3COOH can form hydrogen bonds, whereas HCOOCH_3 cannot. Therefore HCOOCH_3 has weaker intermolecular interactions and has a higher vapor pressure than CH_3COOH . |

To confirm the above reasoning, use boiling points given below to indicate strengths of intermolecular forces. Remember, the lower the boiling point is, the weaker the intermolecular forces present in the liquid, and the higher the vapor pressure at a specific temperature.

Compound	B.P. (°C)	Compound	B.P. (°C)
BiCl_3	447	N_2	-195.8
BiBr_3	453	NO	-151.8
CO	-191.5	CH_3COOH	117.9
CO_2	-78.5 (sublimes)	HCOOCH_3	31.5

$$\begin{aligned} ? \text{ H}_3\text{O}^+ \text{ ions} &= (1.0 \times 10^{10} \text{ H}_2\text{O molecules}) \times \frac{1.0 \text{ mole H}_2\text{O molecules}}{6.02 \times 10^{23} \text{ H}_2\text{O molecules}} \times \frac{1.0 \times 10^{-7} \text{ mol H}_3\text{O}^+ \text{ ions}}{55.6 \text{ mol H}_2\text{O}} \\ &= \mathbf{3.0 \times 10^{-23} \text{ H}_3\text{O}^+ \text{ ions}} \end{aligned}$$

18-18. Refer to Section 18-3 and Appendix A-2.

When working with base 10 logarithms, the number of significant figures in the number (the antilogarithm) sets the number of significant digits in the mantissa (the decimal part of the logarithm). For example in (a), the number 1.0 has two significant figures, so there are 2 decimal places in the log of that number.

- | | | |
|--|---|---------------|
| (a) $\text{pH} = -\log [\text{H}^+] = -\log (1.0) = \mathbf{0.00}$ | $\text{pOH} = 14.00 - \text{pH} = \mathbf{14.00}$ | acidic |
| (b) $\text{pH} = -\log (1.7 \times 10^{-4}) = \mathbf{3.77}$ | $\text{pOH} = 14.00 - 3.77 = \mathbf{10.23}$ | acidic |
| (c) $\text{pH} = -\log (6.8 \times 10^{-8}) = \mathbf{7.17}$ | $\text{pOH} = 14.00 - 7.17 = \mathbf{6.83}$ | basic |
| (d) $\text{pH} = -\log (9.3 \times 10^{-11}) = \mathbf{10.03}$ | $\text{pOH} = 14.00 - 10.03 = \mathbf{3.97}$ | basic |

18-20. Refer to Section 18-3, Examples 18-4 and 18-5, and Table 18-2.

We know: $\text{pH} = -\log [\text{H}_3\text{O}^+] = 7.45$.

Therefore, $[\text{H}_3\text{O}^+] = \text{antilog} (-7.45) = \mathbf{3.5 \times 10^{-8} M}$

If we assume the blood is at 25°C, $[\text{OH}^-] = \frac{K_w}{[\text{H}_3\text{O}^+]} = \frac{1.00 \times 10^{-14}}{3.5 \times 10^{-8}} = \mathbf{2.9 \times 10^{-7} M}$

If we assume the blood is at 37°C (body temperature), $[\text{OH}^-] = \frac{K_w}{[\text{H}_3\text{O}^+]} = \frac{2.4 \times 10^{-14}}{3.5 \times 10^{-8}} = \mathbf{6.9 \times 10^{-7} M}$

18-22. Refer to Sections 18-2 and 18-3, and Example 18-5.

- (a) $[\text{H}_3\text{O}^+] = [\text{HCl}] = 0.20 M$ since HCl is a strong acid $\text{pH} = -\log [\text{H}^+] = -\log (0.20) = \mathbf{0.70}$
- (b) $[\text{H}_3\text{O}^+] = [\text{HNO}_3] = 0.050 M$ since HNO_3 is a strong acid $\text{pH} = -\log [\text{H}^+] = -\log (0.050) = \mathbf{1.30}$
- (c) $[\text{H}_3\text{O}^+] = [\text{HClO}_4] = \frac{0.65 \text{ g HClO}_4}{1 \text{ L}} \times \frac{1 \text{ mol HClO}_4}{100.45 \text{ g HClO}_4} = 6.5 \times 10^{-3} M$ since HClO_4 is a strong acid
 $\text{pH} = -\log (6.5 \times 10^{-3} M) = \mathbf{2.19}$
- (d) $[\text{OH}^-] = [\text{NaOH}] = 9.8 \times 10^{-4} M$ since NaOH is a strong soluble base
 $\text{pOH} = -\log [\text{OH}^-] = 3.01$; $\text{pH} = 14.00 - 3.01 = \mathbf{10.99}$

18-24. Refer to Section 18-3 and Example 18-4.

We know: $\text{pH} = -\log [\text{H}_3\text{O}^+] = 3.52$. Therefore, $[\text{H}_3\text{O}^+] = \text{antilog} (-3.52) = 3.0 \times 10^{-4} M$

Since HNO_3 is a strong acid, $[\text{HNO}_3] = [\text{H}_3\text{O}^+] = \mathbf{3.0 \times 10^{-4} M}$

18-26. Refer to Section 18-3, and Examples 18-5 and 18-6.

	Solution	$[\text{H}_3\text{O}^+]$	$[\text{OH}^-]$	pH	pOH
(a)	0.085 M NaOH	$1.2 \times 10^{-13} M$	0.085 M	12.93	1.07
(b)	0.075 M HCl	0.075 M	$1.3 \times 10^{-13} M$	1.12	12.88
(c)	0.075 M $\text{Ca}(\text{OH})_2$	$6.7 \times 10^{-14} M$	0.15 M	13.18	0.82

18-28. Refer to Section 10-7 and Appendix F.

- (a) H_3PO_4 is probably a slightly stronger acid than H_3AsO_4 . P is probably slightly more electronegative than As, since electronegativity increases upward in a group, even though both are given an electronegativity of 2.1. The P atom would pull the electron density in the O-H bond away from the O-H bond toward itself a

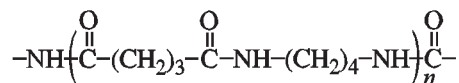
23-108. Refer to Section 23-19.

Copolymers are formed when two different monomers are mixed and then polymerized. It is possible to produce a copolymer by addition polymerization. An example is SBR, the most important rubber produced in the United States. It is a copolymer of styrene and butadiene in a 1:3 ratio.

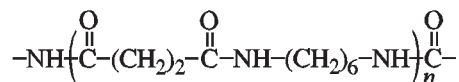
23-110. Refer to Section 23-19.

- (a) Common Nylon is called Nylon 66 because the parent diamine and dicarboxylic acid of Nylon 66 each contain six carbon atoms.
- (b) The parent diamine and dicarboxylic acid of Nylon xy would contain x and y carbon atoms, respectively.

Nylon 45:



Nylon 64:



23-112. Refer to Sections 23-1, 23-2, 23-3 and 23-4.

- (a) C₉H₁₆ (b) C₂₂H₄₄ (c) C₄H₁₀

23-114. Refer to Section 23-15 and Figure 23-20.

- (a) carboxylic acid (b) ester (c) acyl chloride (d) amide

23-116. Refer to Section 23-15 and Figure 23-20.

- | | | | | | | | | |
|-----|---|--|-----|---|---|-----|-------|-------|
| (a) | $\text{R--}\overset{\text{O}}{\parallel}\text{C--R}$ | ketone | (b) | Ar-OH
R-O-R
R ₂ -CH-OH
R ₂ -NH | phenol
ether
secondary alcohol
secondary amine | (c) | R-O-R | ether |
| (d) | Ar-OH
R-O-R
R ₂ -CH-OH
R ₃ -N
C=C | phenol
ether
secondary alcohol
tertiary amine
alkene (double bond) | (e) | Ar-OH
R ₂ -CH-OH
R ₂ -NH | phenol
secondary alcohol
secondary amine | | | |

23-118. Refer to the Sections as stated.

- | | |
|--|--------------------------|
| (a) 3-methyl-1-butanol | (Section 23-9) |
| (b) 2-methylcyclopentanol | (Section 23-9) |
| (c) 2-aminopropane (isopropylamine) | (Section 23-12) |
| (d) 2-chloropropene | (Section 23-3) |
| (e) 1,4-dibromobenzene (<i>p</i> -dibromobenzene) | (Sections 23-5 and 23-8) |
| (f) triethylamine | (Section 23-12) |
| (g) diphenyl ether (phenoxybenzene) | (Section 23-10) |
| (h) 2,4,6-tribromoaniline | (Section 23-12) |