Task 4

Due: 11:59pm on Friday, April 27, 2018

To understand how points are awarded, read the Grading Policy for this assignment.

Conjugate Pairs

According to the Brønsted-Lowry theory, an acid is any substance (molecule or ion) that can transfer a proton (H^+ ion) to another substance, and a base is any substance that can accept a proton. Acid-base reactions are proton-transfer reactions, as follows:

HA	$+$	B	$\rightleftharpoons$	BH^+	$+$	A^-
acid		base		acid		base

Chemical species whose formulas differ only by one proton are said to be conjugate acid-base pairs. Thus, A^- is the conjugate base of the acid HA, and HA is the conjugate acid of the base A^-. Similarly, B is the conjugate base of the acid BH^+, and BH^+ is the conjugate acid of the base B. Strong acids have very weak conjugate bases, and very weak acids have strong conjugate bases.

Part A

The following equation shows the equilibrium in an aqueous solution of ethylamine:

$$C_2H_5NH_2(aq) + H_2O(l) \rightleftharpoons C_2H_5NH_3{}^+(aq) + OH^-(aq)$$

Which of the following represents a conjugate acid-base pair?

Hint 1. How to approach the problem

The simplest way to identify a conjugate acid-base pair is to find the species whose formulas differ only by one proton.

ANSWER:

- ○ $C_2H_5NH_2$ and H_2O
- ○ $C_2H_5NH_3{}^+$ and OH^-
- ◉ H_2O and OH^-
- ○ $C_2H_5NH_2$ and OH^-

Correct

In the presence of ethylamine (a weak base), H_2O acts as an acid and donates a proton. OH^- is a conjugate base of H_2O.

Part B

What is the conjugate base of $HSO_3{}^-$?

Express your answer as a chemical formula.

Hint 1. Determine the conjugate base

Complete the following statement about $HSO_3{}^-$:

ANSWER:

Its conjugate base will have ○ one more / ◉ one less proton.

ANSWER:

$SO_3{}^{2-}$

Correct

Part C

What is the conjugate acid of $HPO_2{}^{2-}$?

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Hint 1. Determine the conjugate acid

Complete the following statement about $HPO_2{}^{2-}$.

ANSWER:

Its conjugate acid will have (●) one more ( ) one less proton.

ANSWER:

$H_2PO_2{}^-$

Correct

Part D

Among three bases, X^-, Y^-, and Z^-, the strongest one is Y^-, and the weakest one is Z^-. Rank their conjugate acids, HX, HY, and HZ, in order of decreasing strength.

Rank the acids from strongest to weakest. To rank items as equivalent, overlap them.

Hint 1. How to approach the problem

A strong base has a strong tendency to be protonated in an aqueous solution; therefore its conjugate acid would have a low tendency to donate a proton. That means the relationship between the strength of a base and the strength of its conjugate acid is inverse: The stronger the base, the weaker its conjugate acid.
If an acid is strong, it is completely dissociated in an aqueous solution, and its conjugate base has a negligible tendency to be protonated (which means this base is very weak).

ANSWER:

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Strongest acid — Weakest acid

HZ HX HY

☐ The correct ranking cannot be determined.

Correct

± Acid-Base Relationships in Water

Water ionizes by the equation

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The extent of the reaction is small in pure water and dilute aqueous solutions. This reaction creates the following relationship between $[H^+]$ and $[OH^-]$:

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$$K_w = [H^+][OH^-]$$

Keep in mind that, like all equilibrium constants, the value of K_w changes with temperature.

Part A

What is the H^+ concentration for an aqueous solution with pOH = 2.57 at 25 $^\circ C$?

Express your answer to two significant figures and include the appropriate units.

Hint 1. Identify the proper formula

Which equation correctly shows how to calculate $[H^+]$ from $[OH^-]$ for an aqueous solution?

ANSWER:

$[H^+]$=

- ○ $\frac{[OH^-]}{K_w}$
- ◉ $\frac{K_w}{[OH^-]}$
- ○ $K_w \times [OH^-]$

Hint 2. Enter the value of K_w at the given temperature

What is the value of K_w at 25 $^\circ C$?

Express your answer numerically.

ANSWER:

K_w = 1.0×10^{-14}

Hint 3. Calculate the hydroxide ion concentration

What is the concentration of OH^- in this solution?

Express your answer to three significant figures and include the appropriate units.

Hint 1. How to calculate hydroxide ion concentration from pOH

Like pH, pOH also involves a negative log. It is defined as

$$pOH = -\log[OH^-]$$

Therefore, $[OH^-]$ is equal to the antilog of the negative pOH:

$$[OH^-] = 10^{-pOH}$$

ANSWER:

$[OH^-]$ = 2.69×10^{-3} M

ANSWER:

$[H^+]$ = 3.7×10^{-12} M

Correct

Part B

Arrange the following aqueous solutions, all at 25 $^\circ C$, in order of decreasing acidity.

Rank from most acidic to most basic. To rank items as equivalent, overlap them.

Hint 1. How to approach the problem

You can use the following relationships to convert each expression to a common quantity such as pH or pOH at 25 $^\circ C$.

$$pH = -\log[H^+]$$

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$$pOH = -\log[OH^-]$$

$$14.00 = \mathrm{pH} + \mathrm{pOH}$$

After you have converted each expression to a common quantity, you can directly compare the relative acidity of each solution.

Hint 2. Convert pOH to pH

What is the pH that corresponds to a pOH of 8.55?

Express your answer numerically.

Hint 1. Equation to use

For aqueous solutions at 25 $^\circ\mathrm{C}$,

$$14.00 = \mathrm{pH} + \mathrm{pOH}$$

ANSWER:

pH = 5.45

Hint 3. Convert the acid concentration to pH

What is the pH of a 0.0023 M aqueous solution of HCl?

Express your answer numerically.

Hint 1. Identify the relationship between the acid and the hydrogen ion concentration

What is the hydrogen ion concentration of an aqueous solution of HCl?

ANSWER:

- (selected) $[\mathrm{H^+}] = [\mathrm{HCl}]$
- $[\mathrm{H^+}] > [\mathrm{HCl}]$
- $[\mathrm{HCl}] > [\mathrm{H^+}]$

ANSWER:

pH = 2.64

Hint 4. Convert the base concentration to pH

What is the pH of a 0.0018 M aqueous solution of KOH at 25 $^\circ\mathrm{C}$?

Express your answer numerically.

Hint 1. Determine the pOH of the potassium hydroxide solution

What is the pOH of a 0.0018 M aqueous solution of KOH?

Express your answer numerically.

Hint 1. Identify the relationship between the base and the hydroxide ion concentration

What is the hydroxide ion concentration in an aqueous solution of KOH?

ANSWER:

- (selected) $[\mathrm{OH^-}] = [\mathrm{KOH}]$
- $[\mathrm{OH^-}] > [\mathrm{KOH}]$
- $[\mathrm{KOH}] > [\mathrm{OH^-}]$

ANSWER:

pOH = 2.74

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ANSWER:

pH = 11.26

ANSWER:

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Most acidic		Most basic
0.0023 *M* HCl	pH = 5.45 pOH = 8.55	0.0018 *M* KOH

The correct ranking cannot be determined.

Correct

Part C

At a certain temperature, the pH of a neutral solution is 7.66. What is the value of K_w at that temperature?

Express your answer numerically using two significant figures.

Hint 1. Identify the proper formula

What is the formula for K_w?

ANSWER:

K_w =

- $\frac{[\mathrm{OH}^-]}{[\mathrm{H}^+]}$
- (selected) $[\mathrm{H}^+][\mathrm{OH}^-]$
- $\frac{[\mathrm{H}^+]}{[\mathrm{OH}^-]}$

Hint 2. Calculate the hydrogen ion concentration

What is the concentration of H^+ for this solution?

Express your answer to three significant figures and include the appropriate units.

Hint 1. How to calculate hydrogen ion concentration from pH

Since pH is the negative log of $[\mathrm{H}^+]$, therefore, $[\mathrm{H}^+]$ is the antilog of the negative pH:

$$[\mathrm{H}^+] = 10^{-\mathrm{pH}}$$

ANSWER:

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2.19×10^{-8} M

Hint 3. Determine the hydroxide concentration

What is the concentration of OH^- for this solution?

Express the molar concentration numerically to three significant figures.

Hint 1. Identify a temperature-independent property of neutral solutions

Which statement is true for all neutral solutions regardless of temperature?

ANSWER:

- $pH = 7$
- $[H^+] = 1.0 \times 10^{-7}$
- (selected) $[H^+] = [OH^-]$

ANSWER:

$[OH^-]$ = 2.19×10^{-8}

ANSWER:

K_w = 4.8×10^{-16}

Correct

± pH of a Strong Acid, a Weak Acid, a Strong Base, and a Weak Base

The pH of a solution is the negative logarithm of the molar concentration of hydronium ion, that is,

$$pH = -\log[H_3O^+]$$

In neutral solutions at 25 $^\circ C$, $[H_3O^+] = 10^{-7}\ M$ and $pH = 7$. As $[H_3O^+]$ increases, pH decreases, so acidic solutions have a pH of less than 7. Basic solutions have a pH greater than 7. The hydroxide and hydronium ion concentrations are related by the the ion-product constant of water, K_w , as follows:

$$K_w = 1.0 \times 10^{-14} = [H_3O^+][OH^-]$$

In the same way as the pH, we can define the pOH as $pOH = -\log[OH^-]$. It follows from the K_w expression that $pH + pOH = 14$.

Part A

Assuming each solution to be 0.10 M , rank the following aqueous solutions in order of decreasing pH.

Rank the solutions from the highest to lowest pH. To rank items as equivalent, overlap them.

Hint 1. How to approach the problem

You do not need to do any calculations to determine the ranking. Instead, classify each solution as acid or base and as strong or weak. The stronger the acid, the lower the pH. The stronger the base, the higher the pH.

Hint 2. Classify the solutions as acid or base and as strong or weak

Classify each solution as strong acid, weak acid, strong base, or weak base.

Drag each item to the appropriate bin.

Hint 1. How to approach the problem

Typically, the formula for an acid begins with H, although it can sometimes end in $COOH$. The easiest way to distinguish a strong acid from a weak acid is to memorize the seven strong acids (HCl, HBr, HI, HNO_3, H_2SO_4, $HClO_4$, $HBrO_4$). Any acid other than these seven must be a weak acid.

The formula for a strong base contains the hydroxide ion, OH^-. The formula for a weak base typically contains nitrogen, N.

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Hint 2. Classify the solutions as acid or base

Classify each of the following solutions as an acid or a base.

Drag each item to the appropriate bin.

ANSWER:

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Acids
- HCl
- HOCl

Bases
- NaOH
- $Ba(OH)_2$
- N_2H_4

ANSWER:

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Strong base
- NaOH
- $Ba(OH)_2$

Weak base
- N_2H_4

Weak acid
- HOCl

Strong acid
- HCl

Hint 3. Compare the strong bases

Assuming each solution to be 0.10 M , which statement is true regarding a solution of NaOH compared to a solution of $\mathrm{Ba(OH)_2}$?

ANSWER:

- ○ Both solutions have the same pH.
- ○ $\mathrm{Ba(OH)_2}$ produces more hydroxide ion and therefore has a lower pH.
- ◉ $\mathrm{Ba(OH)_2}$ produces more hydroxide ion and therefore has a higher pH.

ANSWER:

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Highest pH Lowest pH

$Ba(OH)_2$ | $NaOH$ | N_2H_4 | $HOCl$ | HCl

The correct ranking cannot be determined.

Correct

Now verify this ranking by calculating the pH of each solution.

Part B

Calculate the pH of a 0.10 M solution of barium hydroxide, $Ba(OH)_2$.

Express your answer numerically using two decimal places.

Hint 1. How to approach the problem

$Ba(OH)_2$ is a strong base, so it dissociates completely in aqueous solutions of low concentrations. Each $Ba(OH)_2$ molecule gives two OH^- ions, so the OH^- concentration is twice the initial concentration of the base. From the concentration of OH^- you can calculate the concentration of H_3O^+ and then find the pH.

Hint 2. Find the concentration of the hydroxide ion

What is the OH^- concentration in a 0.10 M solution of $Ba(OH)_2$?

Express your answer to two decimal places and include the appropriate units.

Hint 1. How to approach the problem

$Ba(OH)_2$ is a strong base, so it dissociates completely in aqueous solutions of low concentrations. Each $Ba(OH)_2$ molecule gives two OH^- ions, so the OH^- concentration is twice the initial concentration of the base.

ANSWER:

OH^- concentration = 0.20 M

Hint 3. Calculate the concentration of the hydronium ion

Calculate the concentration of H_3O^+ in a solution if the concentration of OH^- is 0.20 M.

Express your answer to two significant figures and include the appropriate units.

Hint 1. How to approach the problem

Recall that hydroxide and hydronium ion concentrations are related by the the ion-product constant of water, K_w, as follows:

$$K_w = 1.0 \times 10^{-14} = [H_3O^+][OH^-]$$

Solve this equation for $[H_3O^+]$.

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ANSWER:

H_3O^+ concentration = 5.0×10^{-14} M

ANSWER:

pH = 13.30

Correct

According to the mathematical properties of logarithms, the only digits that are significant figures in logarithms are those to the right of the decimal point. The given concentration has two significant figures; therefore the pH should have two digits after the decimal point.

The other way to solve this problem would be to calculate the pOH and then subtract it from 14 to find the pH.

Part C

Calculate the pH of a 0.10 M solution of NaOH.

Express your answer numerically using two decimal places.

Hint 1. How to approach the problem

Because NaOH is a strong base and dissociates completely in aqueous solution, the concentration of OH^- ions is equal to the initial concentration of the base. From the concentration of OH^- you can calculate the H_3O^+ concentration using the K_w constant. (Recall that $[H_3O^+][OH^-] = K_w = 1.0 \times 10^{-14}$.) Then you can find the pH.

Hint 2. Determine the hydroxide ion concentration

What is the concentration of OH^- in a 0.10 M solution of NaOH?

Express your answer to two decimal places and include the appropriate units.

ANSWER:

$[OH^-]$ = 0.10 M

Hint 3. Calculate the concentration of the hydronium ion

What is the concentration of H_3O^+ in a 0.10 M solution of NaOH?

Express your answer to two significant figures and include the appropriate units.

Hint 1. How to approach the problem

Recall that hydroxide and hydronium ion concentrations are related by the the ion-product constant of water, K_w, as follows:

$$K_w = 1.0 \times 10^{-14} = [H_3O^+][OH^-]$$

Solve this equation for $[H_3O^+]$.

ANSWER:

H_3O^+ concentration = 1.0×10^{-13} M

ANSWER:

pH = 13.00

Correct

According to the mathematical properties of logarithms, the only digits that are significant figures in logarithms are those to the right of the decimal point. The given concentration has two significant figures; therefore the pH should have two digits after the decimal point.

The other way to solve this problem would be to calculate the pOH and then subtract it from 14 to get the pH value.

Part D

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Calculate the pH of a 0.10 M solution of hydrazine, N_2H_4. K_b for hydrazine is 1.3×10^{-6}.

Express your answer numerically using two decimal places.

Hint 1. How to approach the problem

Hydrazine is a weak base, so we need to consider the following equilibrium, which uses B as an abbreviation for $\mathrm{N_2H_4}$:

$$\mathrm{B(aq) + H_2O(l) \rightleftharpoons BH^+(aq) + OH^-(aq)}, \qquad K_\mathrm{b} = \frac{\mathrm{[BH^+][OH^-]}}{\mathrm{[B]}}$$

At equilibrium, $\mathrm{[BH^+] = [OH^-]}$, which we will call x. Thus, $\mathrm{[B]}$ at equilibrium is equal to $0.10 - x$. Substitute these values into the K_b expression and solve it for x. Then use $\mathrm{[OH^-]}$ to calculate pH.

Hint 2. Calculate the concentration of the hydroxide ion

Calculate the equilibrium concentration of $\mathrm{OH^-}$ in a 0.10 M solution of $\mathrm{N_2H_4}$.

Express your answer to three significant figures and include the appropriate units.

Hint 1. How to approach the problem

The following table expresses the equilibrium concentrations in terms of the variable x.

	B	+ $\mathrm{H_2O}$ ⇌	$\mathrm{BH^+}$	+ $\mathrm{OH^-}$
Initial concentration (M):	0.10		0	0
Change (M):	$-x$		$+x$	$+x$
Final concentration (M):	$0.10 - x$		x	x

Therefore, $K_b = \frac{x^2}{0.10 - x}$

Because K_b is small, x will also be small compared to 0.10 M. Therefore, we can assume that $0.10 - x$ is approximately equal to 0.10. The equation can then be simplified to $K_b = x^2/0.10$. Finally, solve for x, which is equal to $\mathrm{[OH^-]}$.

ANSWER:

$\mathrm{[OH^-]}$ = 3.61×10^{-4} M

Hint 3. Calculate the concentration of the hydronium ion

Calculate the concentration of $\mathrm{H_3O^+}$ ion in a solution where the concentration of the $\mathrm{OH^-}$ ion is 3.61×10^{-4}.

Express your answer to three significant figures and include the appropriate units.

Hint 1. How to approach the problem

Recall that hydroxide and hydronium ion concentrations are related by the the ion-product constant of water, K_w, as follows:

$$K_w = 1.0 \times 10^{-14} = \mathrm{[H_3O^+][OH^-]}$$

Solve this equation for $\mathrm{[H_3O^+]}$.

ANSWER:

$\mathrm{[H_3O^+]}$ = 2.78×10^{-11} M

ANSWER:

pH = 10.56

Correct

According to the mathematical properties of logarithms, the only digits that are significant figures in logarithms are those to the right of the decimal point. The given concentration has two significant figures; therefore the pH is expressed with two digits after the decimal point.

Part E

Calculate the pH of a 0.10 M solution of hypochlorous acid, HOCl. K_a of HOCl is 3.5×10^{-8}.

Express your answer numerically using two decimal places.

Typesetting math: 48% approach the problem

Hypochlorous acid is a weak acid, so we need to consider the following equilibrium:

$$\mathrm{HOCl(aq)+H_2O(l) \rightleftharpoons H_3O^+(aq)+OCl^-(aq)}, \quad K_a = \frac{[\mathrm{H_3O^+}][\mathrm{OCl^-}]}{[\mathrm{HOCl}]}$$

At equilibrium, $[\mathrm{H_3O^+}] = [\mathrm{OCl^-}]$, which we will call x. Thus, $[\mathrm{HOCl}]$ at equilibrium is equal to $0.10 - x$. Substitute these values into the K_a expression and solve it for x. Then use $[\mathrm{H_3O^+}]$ to calculate pH.

Hint 2. Calculate the concentration of the hydronium ion

Calculate the equilibrium concentration of $\mathrm{H_3O^+}$ in a 0.10 M solution of HOCl.

Express your answer to three significant figures and include the appropriate units.

Hint 1. How to approach the problem

The following table expresses the equilibrium concentrations in terms of the variable x.

	HOCl + $\mathrm{H_2O}$ ⇌	$\mathrm{H_3O^+}$ +	$\mathrm{OCl^-}$
Initial concentration (M):	0.10	0	0
Change (M):	$-x$	$+x$	$+x$
Final concentration (M):	$0.10 - x$	x	x

Therefore, $K_a = x^2/0.10 - x$
Because K_a is small, x will also be small compared to 0.10 M. Therefore, we can assume that $0.10 - x$ is approximately equal to 0.10. The equation can then be simplified to $K_a = x^2/0.10$. Finally, solve for x, which is equal to $[\mathrm{H_3O^+}]$.

ANSWER:

$[\mathrm{H_3O^+}]$ = 5.92×10^{-5} M

ANSWER:

pH = 4.23

Correct

The given concentration has two significant figures; therefore the pH is expressed with two digits after the decimal point.

Part F

Calculate the pH of a 0.10 M solution of HCl.

Express your answer numerically using two decimal places.

Hint 1. Determine the hydronium ion concentration

What is the concentration of $\mathrm{H_3O^+}$ in a 0.10 M solution of HCl?

Express your answer to two decimal places and include the appropriate units.

Hint 1. How to approach the problem

HCl is a strong acid, so it dissociates completely. Thus, the concentration of the hydronium ion will be equal to the initial concentration of the acid.

ANSWER:

$[\mathrm{H_3O^+}]$ = 0.10 M

ANSWER:

pH = 1.00

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Correct

The given concentration has two significant figures; therefore the pH should have two digits after the decimal point.

Definitions of Acids and Bases

There are three ways in which to define acids and bases: the Arrhenius concept, the Brønsted-Lowry concept, and the Lewis concept.

Arrhenius concept

Arrhenius acids are substances that, when dissolved *in water*, increase the concentration of the H^+ ion; Arrhenius bases are substances that, when dissolved *in water*, increase the concentration of the OH^- ion.

For example, a substance with an ionizable protons is an acid:

$$HNO_2(aq) \rightleftharpoons NO_2{}^-(aq) + H^+(aq)$$

A substance that can either directly or indirectly increase hydroxide ions is a base:

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4{}^+(aq) + OH^-(aq)$$

However, the Arrhenius concept only applies to aqueous solution. It does not apply to reactions in other phases, which ultimately lead to the use of other definitions for such systems.

Part A

Using the Arrhenius concept of acids and bases, identify the Arrhenius acid and base in each of the following reactions:

$$LiOH(aq) + HNO_3(aq) \rightarrow LiNO_3(aq) + H_2O(l)$$

$$CH_3NH_2(g) + HBr(g) \rightarrow CH_3NH_3Br(s)$$

Drag the appropriate items to their respective bins.

Hint 1. How to approach the problem

The Arrhenius concept of acids and bases applies only to aqueous solutions. To identify Arrhenius inorganic acids, the acidic hydrogen is usually written first in the formula. For organic (carbon-based) acids, the acidic hydrogen is written last in the formula as part of a carboxyl group, $-COOH$. Inorganic bases often contain OH in the formula for the solute. Weak Arrhenius bases are often derivatives of ammonia, NH_3. First, determine whether the reaction is in an aqueous solution, and then examine the formulas for H and OH or derivatives of NH_3.

Hint 2. Identify Arrhenius acids

Consider aqueous solutions of the following substances. Which solutions increase $[H^+]$ of the solution?

Check all that apply.

ANSWER:

- [ ] $CH_3OH(aq)$
- [x] $H_3PO_4(aq)$
- [ ] $Na_2SO_4(aq)$
- [x] $CH_3COOH(aq)$

Hint 3. Identify Arrhenius bases

Consider aqueous solutions of the following substances. Which solutions increase $[OH^-]$ of the solution?

Check all that apply.

ANSWER:

- [x] $NH_2Cl(aq)$
- [ ] $Na_2SO_4(aq)$
- [ ] $H_3PO_4(aq)$
- [x] $Ca(OH)_2(aq)$

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Arrhenius acid: HNO_3

Arrhenius base: $LiOH$

Neither: CH_3NH_2, HBr

Correct

Brønsted-Lowry concept

Brønsted-Lowry acids are substances that can donate a proton (H^+) to another substance; Brønsted-Lowry bases are substances that can accept a proton (H^+).

A substance with transferable protons is an acid, such as HNO_2 in this example:

$$HNO_2(aq) + H_2O(l) \rightleftharpoons NO_2^-(aq) + H_3O^+(aq)$$

A substance that can receive a transferable proton is a base, such as water in this example:

$$HNO_2(aq) + H_2O(l) \rightleftharpoons NO_2^-(aq) + H_3O^+(aq)$$

One benefit of the Brønsted-Lowry concept of acids and bases is that it is not limited to aqueous solutions and can be applied to gases, liquids, and solids.

Part B

Using the Brønsted-Lowry concept of acids and bases, identify the Brønsted-Lowry acid and base in each of the following reactions:

$$HSO_4^-(aq) + H_2O(l) \rightarrow H_2SO_4(aq) + OH^-(aq)$$

$$(CH_3)_2NH(g) + BF_3(g) \rightarrow (CH_3)_2NHBF_3(s)$$

Drag the appropriate items to their respective bins.

Hint 1. How to approach the problem

The Brønsted-Lowry concept of acids and bases is not limited to aqueous solutions and can be applied to gases, liquids, and solids. To identify Brønsted-Lowry acids, compare the reactant form of the substance to the product form. If the product contains additional hydrogen atom(s), the substance is a Brønsted-Lowry base; it has accepted a proton (hydrogen ion). Conversely, if the product contains fewer hydrogen atom(s), the substance is a Brønsted-Lowry acid; it has donated a proton (hydrogen ion). Examine the formulas for reactants and corresponding products to determine acid-base character.

Hint 2. Predict the product for a Brønsted-Lowry acid

Brønsted-Lowry acids are substances that can donate a proton (H^+) to another substance. If HCO_3^- acts as a Brønsted-Lowry acid, what is the formula for the product formed? Be sure to include any appropriate charges.

Express your answer as a chemical formula.

ANSWER:

CO_3^{2-}

Hint 3. Predict the product for a Brønsted-Lowry base

Brønsted-Lowry bases are substances that can accept a proton (H^+). If $H_2PO_4^-$ acts as a Brønsted-Lowry base, what is the formula for the

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? Be sure to include any appropriate charges.

Express your answer as a chemical formula.

ANSWER:

H_3PO_4

ANSWER:

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Brønsted-Lowry acid	Brønsted-Lowry base	Neither
H_2O	HSO_4^-	$(CH_3)_2NH$, BF_3

Correct

Substances classified as Arrhenius acids and bases are included in the Brønsted-Lowry concept. A substance that can increase $[H^+]$ of water is a proton donor. A substance that can increase $[OH^-]$ of water is a proton acceptor.

Lewis concept

A Lewis acid is an electron-pair acceptor, and a Lewis base is an electron-pair donor.
A substance that accepts an electron pair is an acid, such as Fe^{3+} in this example where a pair of electrons on CN^- is transferred to the metal:

$$Fe^{3+}(aq) + 6CN^-(aq) \rightarrow Fe(CN)_6{}^{3-}(aq)$$

A substance that donates an electron-pair is a base, such as water in this example where a pair of electrons on the oxygen of water are transferred to the metal cation core:

$$[Fe(H_2O)_5]^{2+}(aq) + H_2O(l) \rightleftharpoons [Fe(H_2O)_6]^{3+}(aq)$$

The Lewis concept greatly increases the number of species that can be thought of as acids and bases. It allows cations and species with incomplete octets to be defined as an acid. You can identify a transition metal cation that act as acids by assessing whether a ligand with transferable electrons donates electrons to the metal core.

Part C

Using the Lewis concept of acids and bases, identify the Lewis acid and base in each of the following reactions:

$$Ni(NO_3)_3(s) + 6H_2O(l) \rightarrow Ni(H_2O)_6{}^{3+}(aq) + 3NO_3{}^-(aq)$$

$$CH_3NH_2(g) + HBr(g) \rightarrow CH_3NH_3Br(s)$$

Drag the appropriate items to their respective bins.

Hint 1. How to approach the problem

The Lewis concept of acids and bases is not limited to aqueous solutions and can be applied to gases, liquids, and solids.
Lewis acids are electron-pair acceptors and must have empty orbitals in their valence shells. Common substances that act as Lewis acids are the H^+ ion or any metal ion (M^{n+}) or electron-deficient species such as covalent compounds of Be and B.
Lewis bases are electron-pair donors and have unshared electron (lone) pairs in their valence shells. Common substances that act as Lewis bases are the OH^- ion and many anions as well as neutral compounds in which the central atom is from groups 5A, 6A, and 7A such as H_2O or NH_3.

To determine whether a substance is a Lewis acid or base, compare the reactant form of the substance to the product form of the substance with Typesetting math: 48% ron-pair migration.

Hint 2. Identify an electron-pair acceptor

To identify an electron-pair acceptor, look for a species that is electron deficient, such as a cation or an atom with an incomplete octet. Then identify whether a bond is formed from that species to another by accepting electrons.
When $ZnCl_2(s)$ dissolves in water, $Zn(H_2O)_4{}^{2+}$ forms. The three reactants are Zn^{2+}, Cl^-, and H_2O. Which acts as electron-pair acceptor?

ANSWER:

- (●) Zn^{2+}
- ( ) H_2O
- ( ) Cl^-

Hint 3. Identify an electron-pair donor

To identify an electron-pair donor, look for a species with a lone-pair of electrons not involved in bonding. Then identify whether a species deficient in electrons accepts one of the lone-pairs forming a bond between the two.
When $Cu(NO_3)_2(s)$ dissolves in an ammonia solution, the $Cu(NH_3)_4{}^{2+}$ ion forms. The three reactants are Cu^{2+}, $NO_3{}^-$, and \rm NH_3. Which acts as an electron-pair donor?

ANSWER:

- ( ) \rm {NO_3}^-
- (●) \rm NH_3
- ( ) \rm Cu^{2+}

ANSWER:

Reset Help

Lewis acid	Lewis base	Neither
$Ni(NO_3)_3$, HBr	H_2O, CH_3NH_2	

Correct

The substances classified as Arrhenius acids and bases and Brønsted-Lowry acids and bases are encompassed by the Lewis concept. A substance that can increase \rm [H^+] of water is a proton donor as well as an electron-pair acceptor. A substance that can increase \rm [OH^-] of water is a proton acceptor as well as an electron-pair donor.

Lewis Acids and Bases

By the Brønsted-Lowry definition, acids are proton donors and bases are proton acceptors. By the Lewis definition, acids are electron-pair acceptors, and bases are electron-pair donors. For bases, the two definitions are equivalent such that all Lewis bases are Brønsted-Lowry bases and vice versa.
However, it is possible to have a Lewis acid that is not a Brønsted-Lowry acid. This is because Lewis acids include molecules and cations that have a vacant valence orbital, regardless of whether they have a proton to donate.
Common examples of Lewis acids (that are not Brønsted-Lowry acids) are metal ions, such as \rm Al^{3+} and \rm Cu^{2+}. The following is an example of a Le Typesetting math: 48% n:

\rm Cu^{2+}+4\ddot{N}H_3\rightarrow \rm {Cu(NH_3)_4}^{2+}

\rm \ddot{N}H_3 donates the electron pair to \rm Cu^{2+}. Therefore, \rm \ddot{N}H_3 is a Lewis base, and \rm Cu^{2+} is a Lewis acid.

Part A

Identify the Lewis acid in the following reaction:

\rm Pt^{2+} (aq) + 4NH_3(aq)\rightleftharpoons {Pt(NH_3)_4}^{2+}(aq)

Hint 1. How to approach the problem

The platinum(II) cation has empty 6*s* and 5*d* subshells. The ammonia molecule, $\ddot{N}H_3$, has one lone electron pair. To identify the Lewis acid, determine which molecule or ion accepts an electron pair.

ANSWER:

- (•) \rm Pt^{2+}
- ( ) \rm NH_3
- ( ) \rm {Pt(NH_3)_4}^{2+}

Correct

Each of four \rm NH_3 anions donates a pair of electrons to \rm Pt^{2+}, which has four vacant valence orbitals.

Part B

Classify each of the following as a Lewis acid or a Lewis base.

Drag the appropriate items to their respective bins.

Hint 1. How to approach the problem

Lewis acids have vacant valence orbitals and can accept an unshared electron pair from a Lewis base. Common examples of Lewis acids are cations of metals, such as \rm Al^{3+} and \rm Cu^{2+}. Examples of neutral Lewis acids are halides of group 3A elements, such as \rm BF_3. Additional examples of Lewis acids are oxides of nonmetals, such as \rm SO_2 and \rm SO_3. An anion cannot be a Lewis acid because it already has a negative charge and won't accept more electrons.

ANSWER:

Reset Help

Lewis acids	Lewis bases
Mn^{2+}	OH^-
$SnCl_4$	Br^-
NO_3	CO
	$(CH_3)_2NH$

Correct

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Part C

In the following pair, which species would you expect to be the stronger Lewis acid?

Hint 1. How to approach the problem

A Lewis acid accepts a lone pair of electrons from a Lewis base. Because opposite charges attract, the greater the positive charge on the cation, the greater its ability to attract negatively charged electrons.

ANSWER:

- ○ $\rm Cu^{+}$
- ◉ $\rm Cu^{2+}$

Correct

± Weak Base Calculations

Many common weak bases are derivatives of $\rm NH_3$, where one or more of the hydrogen atoms have been replaced by another substituent. Such reactions can be generically symbolized as

$$\rm NX_3(aq)+H_2O(l)\rightleftharpoons {HNX_3}^+(aq)+OH^-(aq)$$

where $\rm NX_3$ is the base and $\rm {HNX_3}^+$ is the conjugate acid. The equilibrium-constant expression for this reaction is

$$K_{\rm b}=\rm \frac {[{HNX_3}^+][OH^-]}{[NX_3]}$$

where $K_{\rm b}$ is the base ionization constant. The extent of ionization, and thus the strength of the base, increases as the value of $K_{\rm b}$ increases.

$K_{\rm a}$ and $K_{\rm b}$ are related through the equation

$$K_{\rm a} \times K_{\rm b} = K_{\rm w}$$

As the strength of an acid increases, its $K_{\rm a}$ value increase and the strength of the conjugate base decreases (smaller $K_{\rm b}$ value).

Part A

If $K_{\rm b}$ for $\rm NX_3$ is 5.5×10^{-6}, what is the $\rm pOH$ of a 0.175 $\rm M$ aqueous solution of $\rm NX_3$?

Express your answer numerically.

Hint 1. Express the base ionization constant in terms of the hydroxide concentration

The table below, where x represents the change in concentration, shows the molar concentrations of all aqueous species initially and at equilibrium.

Concentration	$\rm NX_3$	$\rm {HNX_3}^+$	$\rm OH^-$
Initial	0.175 $\rm M$	0	0
Change	-x	+x	+x
Equilibrium	0.175 $\rm M$ -x	x	x

The base ionization constant can also be expressed in terms of equilibrium concentrations:

$$K_{\rm b}=\rm \frac {[{HNX_3}^+][OH^-]}{[NX_3]}$$

How would you express $K_{\rm b}$ in terms of x and the initial concentration, 0.175 $\rm M$?

Express $K_{\rm b}$ in terms of x.

ANSWER:

$K_{\rm b}$ = $\frac{x^{2}}{0.175-x}$

Hint 2. Determine the hydroxide ion concentration

What is the hydroxide ion concentration in a 0.175 $\rm M$ aqueous solution of $\rm NX_3$?

Express your answer numerically as a molar concentration.

ANSWER:

$\rm [OH^-]$ = 9.81×10^{-4} M

ANSWER:

\rm pOH = 3.01

Correct

Part B

If \texttip{K_{\rm b}}{K_b} for \rm NX_3 is 5.5×10^{-6}, what is the percent ionization of a 0.325 {\rm \it M} aqueous solution of \rm NX_3?

Express your answer numerically to three significant figures.

Hint 1. How to approach the problem

The number of \rm NX_3 molecules that ionize will be equal to the number of \rm OH^- ions that form. Therefore, the extent of ionization can be expressed as follows:

\large{\rm percent~ionization=\frac {equilibrium~[OH^-]}{initial~[NX_3]}\times 100 \%}

The concentration of \rm OH^- at equilibrium can be calculated by using the \texttip{K_{\rm b}}{K_b} value and the initial concentration of the base.

Hint 2. Express the base ionization constant in terms of the hydroxide concentration

The table below, where \texttip{x}{x} represents the change in concentration, shows the molar concentrations of all aqueous species initially and at equilibrium.

Concentration	\rm NX_3	\rm {HNX_3}^+	\rm OH^-
Initial	0.325{\rm \it M}	0	0
Change	-x	+x	+x
Equilibrium	0.325{\rm \it M} -x	\texttip{x}{x}	\texttip{x}{x}

The equilibrium constant \texttip{K_{\rm b}}{K_b} can also be expressed in terms of equilibrium concentrations as follows:

\large{K_{\rm b}=\rm \frac {[{HNX_3}^+][OH^-]}{[NX_3]}}

How would you express \texttip{K_{\rm b}}{K_b} in terms of \texttip{x}{x} and the initial concentration, 0.325 {\rm \it M} ?

Express \texttip{K_{\rm b}}{K_b} in terms of \texttip{x}{x}.

ANSWER:

\texttip{K_{\rm b}}{K_b} = \large{\frac{x^{2}}{0.325-x}}

Hint 3. Determine the hydroxide ion concentration

What is the hydroxide ion concentration in a 0.325 {\rm \it M} aqueous solution of \rm NX_3?

Express your answer numerically as a molar concentration.

ANSWER:

\rm [OH^-] = 1.34×10^{-3} M

ANSWER:

percent ionization = 0.411 \%

Correct

Since the \texttip{K_{\rm b}}{K_b} value has two significant figures, the percent ionization should actually have only two significant figures as well. It would be rounded to 0.41 \%.

Part C

If \texttip{K_{\rm b}}{K_b} for \rm NX_3 is 5.5×10^{-6} , what is the the {\rm p}K_{\rm a} for the following reaction?

\rm {HNX_3}^+(aq)+H_2O(l)\rightleftharpoons NX_3(aq)+H_3O^+(aq)

Express your answer numerically to two decimal places.

Hint 1. How to approach the problem

In the given reaction, \rm {HNX_3}^+ is acting as the conjugate acid of \rm NX_3. Thus \texttip{K_{\rm a}}{K_a} for \rm {HNX_3}^+ is the equilibrium constant for the reaction of this ion with water, which is the given equation. The constants \texttip{K_{\rm b}}{K_b} and \texttip{K_{\rm a}}{K_a} for a conjugate base-acid pair are related to each other as

K_{\rm w}=K_{\rm a}\cdot K_{\rm b}

where K_{\rm w} = 1.00 \times 10^{-14}. Use this equation to determine the value of \texttip{K_{\rm a}}{K_a} for \rm {HNX_3}^+. The \texttip{K_{\rm a}}{K_a} value can then be converted to the {\rm p}K_{\rm a} by using the following relationship:

{\rm p}K_{\rm a}=-\log K_a

Hint 2. Determine the acid ionization constant for the conjugate acid

What is \texttip{K_{\rm a}}{K_a} for the reaction of \rm {HNX_3}^+ with water?

Express your answer numerically to three significant figures.

Hint 1. Identify the equation to use

Which of the following would be the correct equation to use to find \texttip{K_{\rm a}}{K_a}?

ANSWER:

\texttip{K_{\rm a}}{K_a}=
- ○ K_{\rm b}/K_{\rm w}
- ○ K_{\rm w}\cdot K_{\rm b}
- ◉ K_{\rm w}/K_{\rm b}

ANSWER:

\texttip{K_{\rm a}}{K_a} = 1.82×10^{-9}

ANSWER:

{\rm p}K_{\rm a} = 8.74

Correct

Pause and Predict Video Quiz: Endothermic and Exothermic Reactions

First, launch the video below. You will be asked to use your knowledge of chemistry to predict the outcome of a demonstration. Then, close the video window and answer the questions at right. You can watch the video again at any point to review.

Part A

When \rm HCl (aq) and \rm NaOH (aq) are mixed in a beaker, the beaker feels warm to the touch. What is known about the enthalpy of this reaction?

Hint 1. How does heat transfer relate to enthalpy?

Endothermic reactions absorb heat from the surroundings and exothermic reactions give off heat to the surroundings.

ANSWER:

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- The reaction is endothermic.
- ΔH is positive.
- The reaction is exothermic.
- Heat is absorbed from the surroundings.

Correct

Part B

Consider this combination reaction:
$\rm 2{}Mg(s) + O_2(g) \rightarrow \rm 2{}MgO(s) ~~\Delta \it H \rm = -1204~kJ$

What is the enthalpy for the decomposition of 1 mole of $\rm MgO(s)$ into $\rm Mg(s)$ and $\rm O_2(g)$?

Hint 1. How is the decomposition reaction related to the combination reaction?

The decomposition reaction is the reverse reaction of this combination reaction. Notice that the question is asking for the enthalpy of 1 mole of $\rm MgO$; the combination reaction given is forming 2 moles of $\rm MgO$.

ANSWER:

- 602 kJ/mol
- -1204 kJ/mol
- -602 kJ/mol
- 1204 kJ/mol

Correct

Part C

The enthalpy for the formation of 1 mole of $\rm NH_3(aq)$ is -80.29 $\rm kJ/mol$. What is the $\Delta H_f$for the formation of 3 moles of $\rm NH_3(aq)$?

Hint 1. Does the ΔH of a reaction change with a different amount of product formed?

Enthalpy is an extensive property and the enthalpy for this reaction will be three times the enthalpy of formation for 1 mole of $\rm NH_3(aq)$.

ANSWER:

- $\rm -518 \times 10^3~kJ$
- -240.87 $\rm kJ$
- -83.29 $\rm kJ$
- -26.76 $\rm kJ$

Correct

± Gas Pressure

Learning Goal:

To understand several methods of measuring gas pressure.

Gases exert a measurable pressure (P) on the walls of their container. The SI unit for pressure is the *pascal* ($\rm Pa$). Other pressure units frequently used in chemistry are *millimeters of mercury* ($\rm mmHg$) and *atmospheres* ($\rm atm$). You can convert between units of pressure using conversion factors such as those indicated below.

$$1~\rm atm=760~mmHg=101,325~Pa$$

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Part A

On a rainy day, a barometer reads 745 {\rm mmHg} . Convert this value to atmospheres.

Express your answer numerically in atmospheres.

Hint 1. How to manipulate the conversion factor

Because \rm 760~mmHg=1~atm the conversion factors are:

\large{\rm \frac{1~atm}{760~mmHg}} or \large{\rm \frac{760~mmHg}{1~atm}}

To make sure that you use the conversion factor correctly, always check the units. The initial units should cancel, and the new unit should stay in the numerator.

ANSWER:

0.980 \rm atm

Correct

The standard atmospheric pressure at a sea level is 1 \rm atm (760 \rm mmHg). Higher pressure usually means sunny and dry weather, and lower pressure often brings clouds and precipitation.

Part B

A closed container is filled with oxygen. The pressure in the container is 325 {\rm kPa} . What is the pressure in millimeters of mercury?

Express the pressure numerically in millimeters of mercury.

Hint 1. How to approach the problem

Start by converting the pressure from kilopascals to pascals. Then use the following conversion factor: \rm 760~mmHg = 101,325~Pa.

Hint 2. Convert the pressure to pascals

Convert 325 {\rm kPa} to pascals.

Express the pressure numerically in pascals.

Hint 1. Kilo conversion factor

1000 ~\rm Pa = 1~ \rm kPa.

ANSWER:

3.25×10^5 \rm Pa

ANSWER:

2440 \rm mmHg

Correct

Part C

What is the pressure (in atmospheres) of the gas inside the container connected to an open-end, mercury-filled manometer as shown in the picture? The atmospheric pressure is 0.95 \rm atm.

Express your answer numerically in atmospheres.

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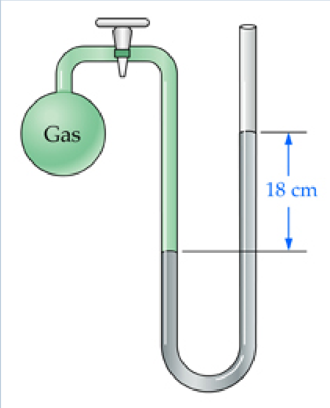

Hint 1. How to approach the problem

In a manometer, the pressure of the gas in the container and the pressure of the gases in the atmosphere both push on the mercury in the U-tube, but from opposite ends. The mercury in the tube will rise or fall depending on whether the pressure in the manometer container or the pressure of the atmosphere is greater. Since the mercury level in the left arm is lower, it indictes that the gas in the container presses on the mercury harder than the outside air does. So the pressure in the container is 18 \rm cmHg higher than the atmospheric pressure.

Hint 2. Convert the difference in mercury levels from centimeters to millimeters

The difference between mercury levels is 18 \rm cm. Convert this value to millimeters.

Express your answer numerically in millimeters.

Hint 1. Conversion factor

1~ \rm cm =10~ \rm mm.

ANSWER:

180 \rm mm

Hint 3. Convert the pressure difference to atmospheres

Convert the pressure difference (180 \rm mmHg) to atmospheres.

Express your answer in atmospheres using two significant figures.

ANSWER:

0.24 \rm atm

ANSWER:

gas pressure = 1.19 \rm atm

Correct

Mercury is used in barometers and manometers because it has the highest density among liquids at room temperature (13.6 \rm g/mL). It is possible to make a manometer filled with any liquid, and it would work, but the tube would need to be much longer. When the density of a liquid is low, relatively small changes in pressure would result in large changes in the level of the liquid.

Animation—P-V Relationships

Watch the video that shows the relationship between pressure and volume for a particular gas. Robert Boyle was the first one to observe the change in the pressure of a gas when its volume is increased or decreased at a constant temperature and the change in the volume of a gas when its pressure is increased or decreased at a constant temperature.

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Part A

Watch the video to determine which of the following relationships are correct according to Boyle's law.

Check all that apply.

Hint 1. Identify a change in volume with a corresponding change in pressure

ANSWER:

According to the video, as the gas pressure increases the gas volume

- ( ) remains constant
- (•) decreases
- ( ) increases

.

ANSWER:

- [x] $\large{V \propto \frac{1}{P}}$
- [ ] $PV \propto V$
- [ ] $PV \propto P$
- [ ] $P \propto V$
- [x] $\large{P \propto \frac{1}{V}}$
- [ ] $V \propto P$

Correct

Boyle's law states that the volume of a gas is inversely proportional to the pressure applied on the gas at constant temperature. As you increase the applied pressure, the volume of the gas decreases accordingly. Mathematically, $P \propto {1}/{V}$ or $V \propto {1}/{P}$.

We can summarize this as $P = {{\it k}}/{V}$ or $V = {{\it k}}/{P}$, where k is the proportionality constant. Thus, $PV = {\rm constant}$.

Part B

Standard temperature and pressure (STP) are considered to be $273 \rm K$ and $1.0 \rm atm$. Predict which of the following changes will cause the volume of the balloon to increase or decrease assuming that the temperature and the gas filling the balloon remain unchanged.

Drag the appropriate items to their respective bins.

Hint 1. How to approach the problem

Consider the change in pressure that the balloon undergoes. Then, use the relationship between the pressure of a gas and its volume as defined by Boyle's law to determine the expected change in volume.
According to Boyle's law, pressure and volume are inversely related to one another. Thus, when pressure increases, volume decreases, and when pressure decreases, volume increases.

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Hint 2. Identify the change in pressure

A balloon filled with helium gas at standard temperature (273 \rm K) and pressure (1.0 \rm atm) is submerged under water, where the pressure is 1.25 \rm atm.

ANSWER:

The pressure of the gas
- ○ remains unchanged
- ◉ increases
- ○ decreases

as the balloon is submerged.

ANSWER:

Reset Help

Volume increases	Volume decreases	Volume is unchanged
Balloon filled with helium under water at 1.15 atm is released and floats to the surface, which is at STP.	Balloon filled with helium at STP is submerged under water where the pressure is 1.25 atm.	Balloon filled with helium at STP floats into air where the pressure equals 1 atm.
Balloon filled with helium at STP floats into the atmosphere where the pressure is 0.5 atm.		

Correct

You may have observed Boyle's law in action if you have seen a syringe being filled. When the stopper is pulled back, the volume in the syringe increases, which causes a decrease in pressure within the tube. This pressure change can be used to pull liquid into the tube.

Part C

A certain gas is present in a 14.0 {\rm L} cylinder at 3.0 {\rm atm} pressure. If the pressure is increased to 6.0 {\rm atm} the volume of the gas decreases to 7.0 {\rm L} . Find the two constants k_{\rm i}, the initial value of k, and k_{\rm f \hspace{1 pt}}, the final value of k, to verify whether the gas obeys Boyle's law.

Express your answers to two significant figures separated by a comma.

Hint 1. How to approach the problem

To find the proportionality constant (k), consider the values of the initial pressure of the gas, 3.0 {\rm atm} , and the initial volume of the gas, 14.0 {\rm L} . Use Boyle's law to calculate the proportionality constant, k_{\rm i} (the initial value of k), for this initial pressure and initial volume of the gas.

Similarly, to calculate k_{\rm f \hspace{1 pt}} (the final value of k) consider the final volume of the gas, 7.0 {\rm L} , and the final pressure of the gas, 6.0 {\rm atm} .

Hint 2. Identify the correct Boyle's law expression

Which of the following is correct according to Boyle's law?

ANSWER:

- ◉ PV = {\rm constant}
- ○ \large{\frac{P}{V} = {\rm constant}}
- ○ \large{\frac{V}{P} = {\rm constant}}

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ANSWER:

$k_{\rm i}, k_{\rm f \hspace{1 pt}}$ = 42,42

Correct

The values for constants $k_{\rm i}$ and $k_{\rm f \hspace{1 pt}}$ are the same and has units of $\rm L \cdot atm$. Thus, at the same temperature the product of pressure and volume for a certain gas is constant. This is in accordance to Boyle's law.

Part D

If a certain gas occupies a volume of 13 $\rm L$ when the applied pressure is 6.5 $\rm atm$, find the pressure when the gas occupies a volume of 3.3 $\rm L$.

Express your answer to two significant figures and include the appropriate units.

Hint 1. How to approach the problem

The volume of a gas at a pressure of 6.5 $\rm atm$ is 13 $\rm L$. Consider the pressure of 6.5 $\rm atm$ as P_1 (initial pressure) and the volume of the gas at this pressure as V_1 (initial volume). Now, calculate the pressure of the gas when the volume is reduced to 3.3 $\rm L$. Consider the volume of 3.3 $\rm L$ as V_2 (final volume) and the pressure of the gas at this volume as P_2 (final pressure). Calculate the final pressure, P_2, using Boyle's law.

Hint 2. Identify the correct equation to determine pressure

According to Boyle's law, the pressure of a gas is inversely related to its volume. Thus for a gas, $PV = {\rm constant}$. If you consider P_1 and P_2 as initial and final pressures and V_1 and V_2 as initial and final volumes, you can say that

$$P_1V_1 = P_2V_2 = {\rm constant}$$

By rearranging the equation $P_1V_1 = P_2V_2$, which of the following formulas can be used to find the final pressure, P_2?

ANSWER:

- ○ $\large{P_2 = \frac{V_2}{P_1V_1}}$
- ○ $\large{P_2 = \frac{P_1}{V_1V_2}}$
- ◉ $\large{P_2 = \frac{P_1V_1}{V_2}}$
- ○ $P_2 = P_1V_1V_2$

ANSWER:

26 $\rm atm$

Correct

The initial volume (V_1) is $\rm 13{\rm L}$ and the initial pressure (P_1) is $\rm 6.5{\rm atm}$; the final volume (V_2) is $\rm 3.3{\rm L}$.

Using $P_1V_1 = P_2 V_2$ you get $P_2 = {P_1V_1}/{V_2} \rm = ({6.5\times13})/3.3 = 26 {\rm atm}$.

± Deriving Gas Law Formulas

Learning Goal:

To understand how to determine the appropriate formula for a given gas law problem.

When you are unsure of which formula to use to solve a gas law problem, it is often helpful to make a chart of initial and final values of pressure \texttip{P}{P}, volume \texttip{V}{V}, number of moles, \texttip{n}{n}, and temperature \texttip{T}{T}, as shown in the table.

	Initial	Final
\texttip{P}{P}	~	~
\texttip{V}{V}	~	~
\texttip{n}{n}	~	~
\texttip{T}{T}	~	~

This type of chart will help you to determine which quantities are changing and which quantities remain the same. For example, use the formula $P_1V_1=P_2V_2$ for the product of pressure and volume at two different points in time when pressure and volume are changing but the number of moles of gas and the temperature are constant. Here is how this formula is derived from the ideal gas law, $PV=nRT$:

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1. [illegible]nd \texttip{T}{T} are constant, the entire quantity nRT is constant.
2. Therefore, PV is constant.

3. It follows that the quantity PV at any point in time will be the same value as at any other point in time.
4. Therefore, P_1V_1=P_2V_2.

Now imagine an experiment where your chart looks like this:

	Initial	Final
\texttip{P}{P}	2 \rm atm	2 \rm atm
\texttip{V}{V}	1.7 \rm L	2.5 \rm L
\texttip{n}{n}	0.45 \rm mol	0.45 \rm mol
\texttip{T}{T}	273 \rm K	?

It is clear that \texttip{V}{V} and \texttip{T}{T} are the quantities that are changing, while \texttip{P}{P} and \texttip{n}{n} are constant. To put all constants \texttip{P}{P}, \texttip{n}{n}, and \texttip{R}{R} together, we need to do a little bit of algebra:

1. PV = nRT.
2. V = {nRT \over P}.
3. {V \over T} = {nR \over P}.
4. {V \over T} is constant.
5. Therefore the quantity {V / T} at any point in time will be the same value as at any other point in time, so

\large{\frac{V_1}{T_1} = \frac{V_2}{T_2}}

This last equation is the best formula to use when only volume and temperature are changing.

Now to solve for the missing value, simply substitute numbers into this formula:

{\rm 1.7~L \over 273~K}= {2.5~{\rm L} \over {T_2}}

which gives

T_2= 401.5~\rm{K}

Derive a gas law formula for a specific scenario

One mole of an ideal gas is sealed in a 22.4-\rm L container at a pressure of 1 \rm atm and a temperature of 273 \rm K. The temperature is then increased to 309 {\rm \;K} , but the container does not expand. What will the new pressure be?

Part A

The most appropriate formula for solving this problem includes only which variables?

Enter the required variables, separated by commas (e.g., `P,V,T`).

Hint 1. How to approach the problem

The formula should include only quantities that are changing.

Hint 2. Make a chart

Fill in this chart.

	Initial	Final
\texttip{P}{P}	~	~
\texttip{V}{V}	~	~
\texttip{n}{n}	~	~
\texttip{T}{T}	~	~

In which box should you put a question mark?

ANSWER:

- ○ initial \texttip{P}{P}
- ◉ final \texttip{P}{P}
- ○ initial \texttip{V}{V}
- ○ final \texttip{V}{V}
- ○ initial \texttip{n}{n}
- ○ final \texttip{n}{n}
- ○ initial \texttip{T}{T}
- ○ final \texttip{T}{T}

Typesetting math: 48%

P,T

Correct

Since temperature increases, it must be included in your formula. Since you are solving for pressure, it must also be included. However, since the number of moles and the volume remain the same, they can be excluded.

Part B

You have determined in Part A that \texttip{P}{P} and \texttip{T}{T} are the only variables needed in the formula. Which of the following relationships holds?

Hint 1. How to approach the problem

Rearrange the ideal gas law PV=nRT such that \texttip{P}{P} and \texttip{T}{T} are on the same side of the equation.

ANSWER:

- ○ PT is constant.
- ◉ {P \over T} is constant.

Correct

Since the quantity {P /T} is constant, it follows that {P_1/ T_1} = {P_2 / T_2}.

Part C

Solve the problem stated in the problem introduction by finding the new pressure.

Express your answer with the appropriate units.

Hint 1. Set up the equation

You have determined that {P_1 / T_1} = {P_2 / T_2}. Which of the following correctly substitutes the values from the introduction into this equation?

ANSWER:

- ◉ {\rm 1~atm \over 273~K} = {P_2 \over \rm 305~K}
- ○ {\rm 1~atm \over 305~K} = {P_2 \over \rm 273~K}
- ○ {\rm 273~K \over 1~atm} = {P_2 \over \rm 305~K}
- ○ {\rm 305~K \over 1~atm} = {P_2 \over \rm 273~K}

ANSWER:

\texttip{P_{\rm 2}}{P_2} = 1.13 {\rm atm}

Correct

The numbers of moles and liters were given, but they are not necessary for solving the problem.

± Gas Density and Molar Mass

Pressure and temperature affect the amount of space between gas molecules, which affects the volume and, therefore, the density of the gas since

\large{\rm density=\frac{mass}{volume}}

The molar mass of a substance, however, is a constant and can be used to identify an unknown gas sample. Molar mass is found by dividing the mass of a sample (in grams) by the number of moles in that sample. The number of moles of gas can be calculated using the ideal gas law

PV=nRT

which can be rearranged as

\large{n=\frac{PV}{RT}}

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Given the number of moles of a gas and its molar mass, you can calculate the mass of the gas. Since density is equal to the ratio of the mass and volume, you can then divide by the volume to find density.

Alternatively, you can use the ratio \texttip{n/V}{n/V} from the ideal gas equation where \texttip{n}{n} is the number of moles and \texttip{V}{V} is the volume, and convert from moles per unit volume to grams per unit volume using molar mass

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Part A

Calculate the density of oxygen, \rm O_2, under each of the following conditions:

- STP
- 1.00 \rm atm and 20.0 {\rm ~^\circ\rm C}

Express your answers numerically in grams per liter. Enter the density at STP first and separate your answers by a comma.

Hint 1. How to approach the problem

This calculation can be done by choosing an arbitrary volume. To make the calculations simpler, assume that you have two 1.00-\rm L samples of oxygen. For each sample, find the number of moles of oxygen using the ideal gas law (PV=nRT). Then convert moles to grams using the molar mass of \rm O_2. Finally, calculate the density of each sample by dividing the mass of the sample by the volume.

Hint 2. Calculate how many moles are in 1 L at STP

How many moles of oxygen gas occupy 1.00 \rm L at STP?

Express your answer numerically in moles.

Hint 1. How to approach the problem

STP stands for the standard temperature and pressure: 0 ^\circ\rm C and 1 \rm atm. Assume that these values have infinite significant figures.

Calculate the number of moles using the ideal gas law

PV=nRT

Solve this equation for \texttip{n}{n} and substitute the given data. Make sure that you use the Kelvin temperature and R=0.08206 \;\rm L\cdot atm/(mol\cdot K).

ANSWER:

\texttip{n}{n} at STP = 4.46×10^{-2} \rm mol

Hint 3. Calculate the number of moles in 1 L at 20.0 ^\circ\rm C

How many moles of oxygen gas occupy 1.00 \rm L at 1.00 \rm atm and 20.0 {\rm ~^\circ\rm C} ?

Express your answer numerically in moles.

Hint 1. How to approach the problem

Calculate the number of moles using the ideal gas law

PV=nRT

Solve this equation for \texttip{n}{n} and substitute the given data. Make sure that you use the Kelvin temperature and R=0.08206\; \rm L\cdot atm/(mol\cdot K).

ANSWER:

\texttip{n}{n} at 20.0 {\rm ~^\circ\rm C} = 4.16×10^{-2} \rm mol

Hint 4. Find the molar mass of \rm O_2

What is the molar mass of \rm O_2?

Express your answer numerically in grams per mole.

Hint 1. How to calculate the molar mass

According to the periodic table, the molar mass of \rm O is 16.0 \rm g/mol. Find the molar mass of \rm O_2.

ANSWER:

molar mass \rm O_2 = 32.0 \rm g/mol

Hint 5. Calculate the mass of 1.00 L of \rm O_2 at STP

What is the mass of 0.0446 \rm mol of \rm O_2?

Express your answer numerically in grams.

ANSWER:

mass of 1.00 \rm L \rm O_2 at STP = 1.43 \rm g

Hint 6. Calculate the mass of 1.00 L of \rm O_2 at 20.0 ^\circ\rm C

Calculate the the mass of 0.0416 {\rm mol} of \rm O_2.

Express your answer numerically in grams.

ANSWER:

mass of 1.00 \rm L \rm O_2 at 20.0 {\rm ~^\circ\rm C} = 1.33 \rm g

ANSWER:

density at STP, density at 1 \rm atm and 20.0 {\rm ~^\circ\rm C} = 1.43,1.33 \rm g/L

Correct

When temperature increases, a gas expands and its density decreases.

Part B

To identify a diatomic gas (\rm X_2), a researcher carried out the following experiment: She weighed an empty 4.8-\rm L bulb, then filled it with the gas at 1.00 {\rm atm} and 23.0 {\rm ~^\circ\rm C} and weighed it again. The difference in mass was 5.5 {\rm g} . Identify the gas.

Express your answer as a chemical formula.

Hint 1. How to approach the problem

Using the ideal gas law, we can calculate how many moles of the gas the sample contains. Dividing the mass by the number of moles will give us the molar mass of the gas. Then we can identify the compound by its molar mass.

Hint 2. Calculate the number of moles in the sample

At 1.00 {\rm atm} and 23.0 {\rm ~^\circ\rm C} , how many moles of the gas does a 4.8-\rm L sample contain?

Express your answer numerically in moles.

Hint 1. How to approach the problem

Calculate the number of moles using the ideal gas law

PV=nRT

Solve this equation for 0.196 {\rm mol} and substitute the given data. Make sure that you use the Kelvin temperature and R=0.08206 \;\rm L\cdot atm/(mol\cdot K).

ANSWER:

\texttip{n}{n} = 0.196 \rm mol

Hint 3. Calculate the molar mass

Calculate the molar mass of a compound if 0.196 {\rm mol} of it has a mass of 5.5 {\rm g} .

Express your answer numerically in grams per mole.

Hint 1. How to approach the problem

Molar mass, in grams per mole, can be found by dividing the mass (in grams) by the number of moles:

\large{\rm molar~ mass=\frac {\rm mass}{\rm number ~of~ moles}}

ANSWER:

molar mass = 28.0 \rm g/mol

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ANSWER:

\rm{\rm{N_{2}}}

Correct

± Dalton's Law of Partial Pressure

A 1.00 \rm L flask is filled with 1.00 {\rm g} of argon at 25 {\rm ^\circ C}. A sample of ethane vapor is added to the same flask until the total pressure is 1.450 {\rm atm} .

Part A

What is the partial pressure of argon, \texttip{P_{\rm Ar}}{P_Ar}, in the flask?

Express your answer to three significant figures and include the appropriate units.

Hint 1. How to approach the problem

First calculate the number of moles of argon in the flask. Then, use the ideal gas equation to find the partial pressure of argon in the flask.

Hint 2. Calculate the number of moles of argon

How many moles \texttip{n_{\rm Ar}}{n_Ar} of argon are present in a 1.00-\rm g sample of argon?

Express your answer to four decimal places and include the appropriate units.

Hint 1. Determine the molar mass of argon

What is the molar mass of argon?

Express your answer in grams per mole using five significant figures.

ANSWER:

39.95 \rm g/mol

ANSWER:

\texttip{n_{\rm Ar}}{n_Ar} = 0.0250 {\rm mol}

Hint 3. Calculate the initial pressure of argon

Use the ideal gas equation to calculate the pressure \texttip{P}{P} of a 1.00-\rm g sample of argon at 25 {\rm ^\circ C} in a 1-\rm L flask.

Express your answer to three significant figures and include the appropriate units.

Hint 1. How to use the ideal gas equation

The ideal gas equation states that PV = nRT. You need to rearrange the equation to solve for pressure, \texttip{P}{P}.

ANSWER:

\texttip{P}{P} = 0.612 {\rm atm}

Hint 4. Identify the method for determining the partial pressure of argon

How is the initial pressure of argon related to the partial pressure of argon after ethane vapor is added?

ANSWER:

The initial pressure of argon is
- ○ less than
- ◉ the same as
- ○ greater than

the partial pressure of argon after ethane is added.

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ANSWER:

\texttip{P_{\rm Ar}}{P_Ar} = 0.612 {\rm atm}

Correct

Before ethane was added, the percent by volume of argon in the flask was 100\% and the partial pressure of argon was equivalent to the total pressure of the flask. The total volume of the flask, the temperature of the flask, and the amount of argon remain constant after ethane was added; therefore the partial pressure of argon is the same before and after ethane was added. The total pressure of the flask is now equal to the combined partial pressures of both argon and ethane.

Part B

What is the partial pressure of ethane, \texttip{P_{\rm ethane}}{P_ethane}, in the flask?

Express your answer to three significant figures and include the appropriate units.

Hint 1. How to approach the problem

Use Dalton's law of partial pressures to find the partial pressure of ethane given the total pressure of the flask and the partial pressure of argon.

Hint 2. Identify the correct equation

Choose the correct equation to calculate the partial pressure of ethane.

ANSWER:

- ○ {P_{\rm ethane} = P_{\rm total} + P_{\rm argon}}
- ◉ {P_{\rm ethane} = P_{\rm total} - P_{\rm argon}}
- ○ {P_{\rm ethane} = P_{\rm total} \times P_{\rm argon}}
- ○ \large{{P_{\rm ethane} = \frac {P_{\rm total}}{ P_{\rm argon}}}~}

ANSWER:

\texttip{P_{\rm ethane}}{P_ethane} = 0.838 {\rm atm}

Correct

Dalton's law of partial pressures states that the total pressure of a system is equal to the sum of the partial pressures of the component gases in the mixture. The expression for Dalton's law of partial pressure is

{P_{\rm total} = P_{\rm A} + P_{\rm B} + \dots}

The partial pressure of an individual gas can be used in stoichiometric calculations involving chemical reactions.

± Partial Pressure and the Ideal Gas Law

The ideal gas law, PV=nRT is independent of the kind of gas. In other words, the pressure exerted by a given number of ideal gas particles is the same whether the sample consists of all one type of particle or a mixture of different kinds of particles.

Therefore, the pressure exerted by a mixture of gases can be expressed as follows:

P_{\rm total} = {(n_1 + n_2 + n_3 +\cdots)RT \over V} = {n_{\rm total}RT \over V}

A *partial pressure* is the pressure exerted by just one type of gas in a mixture. A partial pressure is calculated using only the number of moles of that particular gas, instead of the total number of moles:

P_1 = {n_1RT \over V}, \quad P_2 = {n_2RT \over V}, \quad P_3 = {n_3RT \over V},\quad etc.

The sum of the partial pressures is equal to the total pressure in the mixture:

P_{\rm total}=P_1 + P_2 + P_3 +\cdots

Air is about 78.0% nitrogen molecules and 21.0% oxygen molecules. Several other gases make up the remaining 1% of air molecules.

Part A

What is the partial pressure of nitrogen in air at atmospheric pressure (1 atm)? Assume ideal behavior.

Express your answer to three significant figures and include the appropriate units.

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Hint 1. How to approach the problem

The number of molecules of a gas is directly related to the number of moles of that gas. The number of moles of a gas is directly related to its partial pressure (because volume and temperature must be the same for all the gases in a mixture). Therefore, if 78.0% of the air molecules are nitrogen, then 78.0% of the moles are nitrogen, and also 78.0% of the total pressure is due to the presence of nitrogen.

ANSWER:

0.780 {\rm atm}

Correct

Part B

An "empty" container is not really empty if it contains air. How may moles of nitrogen are in an "empty" two-liter cola bottle at atmospheric pressure and room temperature (\rm 25^{\circ}C)? Assume ideal behavior.

Express your answer to three significant figures and include the appropriate units.

Hint 1. How to approach the problem

The partial pressure of nitrogen is equal to {nRT /V}, where \texttip{n}{n} is the number of moles of nitrogen. Therefore, by rearranging the equation we get that the number of moles of nitrogen is equal to {PV /RT}, where \texttip{P}{P} is the partial pressure of nitrogen.

ANSWER:

6.38×10^{-2} {\rm mol}

Correct

Part C

What is the partial pressure of oxygen in air at atmospheric pressure (1 atm)? Assume ideal behavior.

Express your answer to two decimal places and include the appropriate units.

Hint 1. How to approach the problem

The number of molecules of a gas is directly related to the number of moles of that gas. The number of moles of a gas is directly related to its partial pressure (because volume and temperature must be the same for all the gases in a mixutre). Therefore, if 21.0% of the air molecules are oxygen, then 21.0% of the moles are oxygen, and also 21.0% of the total pressure is due to the presence of oxygen.

ANSWER:

0.21 {\rm atm}

Correct

Part D

An "empty" container is not really empty if it contains air. How may moles of oxygen are in an "empty" two-liter cola bottle at atmospheric pressure (1 \rm atm) and room temperature (\rm 25^{\circ}C)? Assume ideal behavior.

Express your answer to three significant figures and include the appropriate units.

Hint 1. How to approach the problem

The partial pressure of nitrogen is equal to {nRT /V}, where \texttip{n}{n} is the number of moles of nitrogen. Therefore, by rearranging the equation we get that the number of moles of nitrogen is equal to {PV /RT}, where \texttip{P}{P} is the partial pressure of nitrogen.

ANSWER:

1.72×10^{-2} {\rm mol}

Correct

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Boyle's Law

In the mid 1600s, the Irish chemist Robert Boyle carried out experiments that determined the quantitative relationship between the pressure and volume of a gas. His data showed that for gas at a constant temperature, pressure and volume are *inversely proportional*.

Part A

According to Boyle's law, for a fixed quantity of gas at a given temperature, what quantity relating pressure \texttip{P}{P} and volume \texttip{V}{V} is constant?

Hint 1. Inverse proportionality

Two quantities are inversely proportional if one quantity is equal to a constant divided by the other. Thus if one of the quantities is halved, the other will double. Boyle's law states that volume \texttip{V}{V} and pressure \texttip{P}{P} are inversely proportional. Thus, for example, if V=6, P=5 and the volume of a gas at constant temperature is halved, so that V=3, the pressure would have to double, so that P=10.

ANSWER:

- ○ {P \over V}
- ◉ {P \times V}
- ○ P + V
- ○ {V \over P}

Correct

Application of Boyle's law

A 12-liter tank contains helium gas pressurized to 160 \rm atm.

Part B

What size tank would be needed to contain this same amount of helium at atmospheric pressure (1 \rm atm)?

Express the size in liters to three significant figures.

Hint 1. Inverse proportionality

The pressure is being *decreased* by a factor of 160. Therefore the volume must *increase* by a factor of 160.

ANSWER:

1920 \rm L

Correct

Part C

How many 3-liter balloons could the 12-L helium tank pressurized to 160 \rm atm fill? Keep in mind that an "exhausted" helium tank is not empty. In other words, once the gas inside the tank reaches atmospheric pressure, it will no longer be able to fill balloons.

Express the volume in liters to three significant figures.

Hint 1. Determine the volume of "unused" helium

What volume of unused helium will remain in the tank once it reaches atmospheric pressure?

Express the volume in liters to two significant figures.

Hint 1. How to approach the problem

You don't need to think too hard about this question. At any pressure, a 12-liter tank contains 12 liters.

ANSWER:

12 \rm L

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Hint 2. Determine the volume of "usable" helium

What is the total volume of uncompressed helium that can be used toward filling balloons?

Express the volume in liters to four significant figures.

Hint 1. How to approach the problem

You have determined that you have a total of 1920 liters of uncompressed helium. Subtract the number of liters of unused helium to obtain the number of liters of usable helium.

ANSWER:

1908 \rm L

ANSWER:

636 balloons

Correct

± Avogadro's Law

If one had a parking garage that was filled with cars such that each parking spot was occupied, it would make intuitive sense that if we had twice as many cars, the parking garage would need to be twice as big to maintain car density within the garage. But, is the same thing true if one is concerned with gas particles and not cars? The answer is Yes. More than a century ago Italian chemist Amadeo Avogadro postulated that \texttip{V}{V}, the volume of a gas and \texttip{n}{n}, the number of gas particles are directly proportional, when the temperature and pressure are held constant.

Part A

Avogadro's Law states that at a given temperature and pressure, what quantity is constant?

Hint 1. Direct relationship

A direct relationship means that if one value is doubled the other will also double (like the oranges and the size of their container). For example, if \texttip{V}{V} \rm =3 L and \texttip{n}{n} \rm = 2 moles and we double the amount such that \texttip{n}{n} \rm = 4 moles, the volume would have to double such that \texttip{V}{V} \rm =6 L. Which of the following is a true statement?

ANSWER:

- (selected) {3 \over 2} = {6 \over 4}
- 3{\times}2 = 6{\times}4
- 3+2 = 6+4

ANSWER:

- V+n
- V\times n
- (selected) \large{\frac{V}{n}}

Correct

Since \texttip{V}{V} and \texttip{n}{n} are directly proportional, the quantity \large{\frac{V}{n}} will always have the same value at a given pressure and temperature.

Part B

If it takes three "breaths" to blow up a balloon to 1.2 \rm L, and each breath supplies the balloon with 0.060 moles of exhaled air, how many moles of air are in a 3.0 \rm L balloon?

Express your answer to two decimal places and include the appropriate units.

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Hint 1. How to approach the problem

First, determine the number of moles of air in the smaller balloon. Then use the formula: {V_1 \over n_1} = {V_2 \over n_2} to solve for \rm n_2.

Hint 2. Calculate n_1

How many moles of gas are in the smaller balloon if it contains three breaths of 0.060 moles each.

Express your answer to two decimal places and include the appropriate units.

ANSWER:

n_1 = 0.18 {\rm mol}

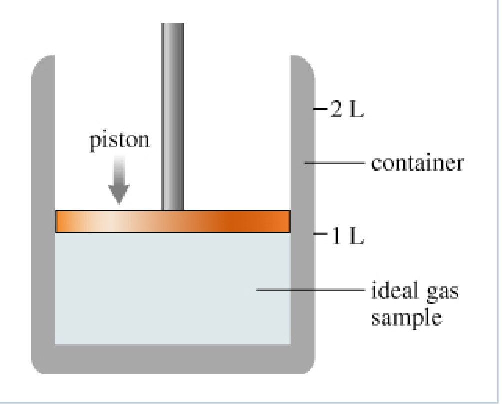
ANSWER:

0.45 {\rm mol}

Correct

± Gas Laws

This figure shows a container that is sealed at the top by a movable piston. Inside the container is an ideal gas at 1.00 \rm atm, 20.0 ^{\circ}{\rm C}, and 1.00 \rm L. This information will apply to all parts of this problem A, B, and C.



Part A

What will the pressure inside the container become if the piston is moved to the 1.20 \rm L mark while the temperature of the gas is kept constant?

Express your answer with the appropriate units.

Hint 1. Determine the relationship between variables

What type of relationship do \texttip{P}{P} and \texttip{V}{V} have in this situation?

ANSWER:

- They are directly proportional
- They are inversely proportional
- They are equal
- There is no relationship

ANSWER:

\texttip{P}{P} = 0.833 {\rm atm}

Correct

P Typesetting math: 48%

The gas sample has now returned to its original state of 1.00 \rm atm, 20.0 \rm{^\circ}C and 1.00 \rm L. What will the pressure become if the temperature of the gas is raised to 200.0 \rm{^\circ}C and the piston is *not* allowed to move?

Express your answer with the appropriate units.

Hint 1. Determine the relationship between variables

What type of relationship do \texttip{P}{P} and \texttip{T}{T} have in this situation?

ANSWER:

- (selected) They are directly proportional
- They are inversely proportional
- They are equal
- There is no relationship

ANSWER:

\texttip{P}{P} = 1.61 {\rm atm}

Correct

Part C

The gas described in parts A and B has a mass of 1.66 grams. The sample is most likely which monoatomic gas?

Type the elemental symbol of the gas below.

Hint 1. How to approach the problem

First, find moles using the ideal gas law (use the pressure, volume and temperature given in the introduction). Next, determine the molar mass in g/mol by dividing grams over moles. Finally, look at the periodic table to see which gas has that molar mass.

Remember that the ideal gas law is PV=nRT where R=0.0821\;\rm{L\cdot atm \over mol\cdot K}

Hint 2. Determine the number of moles

How many moles of gas are there in this sample?

Express your answer with the appropriate units.

Hint 1. What numbers do I use?

While any set of values given in this problem will work, it's easiest to use the original state of this gas: P = 1.00~ \rm atm, V = 1.00~ \rm L, and T = \rm 20.0^{\circ}C.

ANSWER:

n = 4.16×10^{-2} {\rm mol}

Hint 3. Determine molar mass

What is the molar mass of the gas?

Express your answer with the appropriate units.

ANSWER:

molar mass = 39.9 \large{{\rm \frac{g}{mol}}}

ANSWER:

symbol = Ar

Correct

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Score Summary:

Your score on this assignment is 124%.
You received 124.12 out of a possible total of 100 points.

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