

This print-out should have 50 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

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**001 10.0 points**

What is the dominant species in solution at the equivalence point of a weak base-strong acid titration?

1. Weak acid **correct**
2. Strong base
3. Neutral salt
4. Weak base
5. Equal parts weak acid and weak base
6. Strong acid

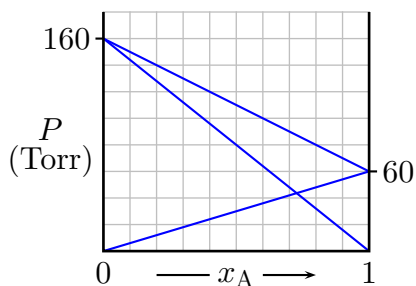
**Explanation:**

The dominant species in solution at the equivalence point will be the conjugate of the analyte. In this case, the dominant species in solution will be the conjugate of the weak base, which is just a weak acid.

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**002 10.0 points**

A and B are mildly volatile solvents. A mixture is made by combining 2 moles of A with 3 moles of B. Interpret the diagram below to determine the vapor pressure of this mixture.



1. 90 Torr
2. 110 Torr
3. 130 Torr
4. 150 Torr

5. 140 Torr

6. 70 Torr

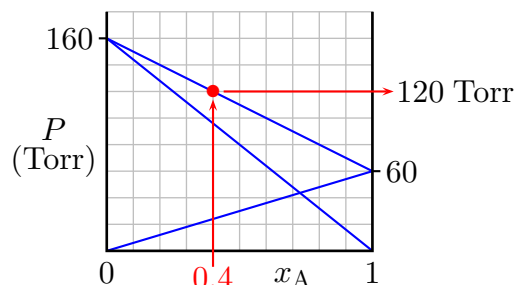
7. 120 Torr **correct**

8. 80 Torr

9. 100 Torr

**Explanation:**

Mixing 2 mol A and 3 mol B is a 2/5 mol fraction of A, or 0.4. Each vertical grid line is 0.1 mol fraction units, so counting 4 over we have the right line. Following it all the way up to the mixture vapor pressure we get 120 Torr (see diagram below). Alternatively, you can use Raoult's Law and Dalton's law to take the sum of partial pressures, which is simply 120 torr = 0.4(60) + 0.6(160)




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**003 10.0 points**

A reaction has a negative change in entropy. This reaction can only be spontaneous if...

1. heat is absorbed at a sufficiently high temperature
2. heat is released at a sufficiently low temperature **correct**
3. heat is released at any temperature
4. heat is absorbed by the system at any temperature
5. None of these choices are correct because a reaction with a negative change in entropy can never be spontaneous

**Explanation:**

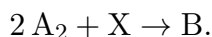
A reaction must have at least one favorable

term between entropy and enthalpy in order to be spontaneous. The negative entropy term is unfavorable, meaning the reaction must be exothermic (heat is released). Moreover, the reaction will only have a negative free energy change if the temperature is small enough. Conceptually, this is because the energy must be able to flow from the system to the low temperature surroundings.

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**004 10.0 points**

Consider the following overall reaction:



Using the overall reaction, determine the rate law for the following mechanism:



1. Rate =  $k' [Z] [X]$

2. Rate =  $k' [A_2] [Z] [X]$

3. Rate =  $k' [A_2]^2$

4. Rate =  $k' [A_2]^2 [X]$

5. Rate =  $k' [A_2] [X]$  **correct**

6. Rate =  $k' [Z][Y]$

**Explanation:**

The slowest step is the rate determining step and is used to write the rate law:

$$\text{Rate} = k_2 [Z] [Y]$$

For the final answer, we need the rate law in terms of only the reactants of the overall reaction. We need to substitute in for  $[Z]$  using the previous fast step in equilibrium:

$$k_1 [A_2] [X] = k_{-1} [Z][Y]$$

$$[Z] = \frac{k_1 [A_2] [X]}{k_{-1} [Y]}$$

If you fit this into your original rate law, you will see that  $[Y]$  cancels out:

$$\text{Rate} = \frac{k_2 k_1 [A_2] [X] [Y]}{k_{-1} [Y]}$$

So our final answer is just:

$$\text{Rate} = k' [A_2] [X]$$

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**005 10.0 points**

Using an electroplating system operating at 7.35 amps, it take 1.50 hours to plate out 5.00 grams of an unknown metal from its molten chloride salt,  $MCl_2$ . Identify the metal M.

1. Mg **correct**

2. Cd

3. Cu

4. Fe

5. Zn

**Explanation:**

$$\frac{I \cdot t}{n \cdot F} = \text{moles of metal}$$

$$\frac{7.35 (1.5 \times 60 \times 60)}{2 \cdot 96485} = .206 \text{ mol metal}$$

$$\text{molar mass} = 5 \text{ g} / .206 \text{ mol} = 24.3 \text{ g}$$

This matches the molar mass of Mg.

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**006 10.0 points**

A 19.7 g sample of an unknown salt (formula =  $MX_2$ ) is dissolved in 249.4 mL water. The boiling point of water in this solution is  $100.657^\circ\text{C}$ . What is the molecular weight of the unknown salt?

1. 185 g/mol **correct**

2. 61.6 g/mol

3. 46.1 g/mol

4. 129.8 g/mol

5. 55.4 g/mol

**Explanation:**

Using the equation  $\Delta T = i \cdot k_b \cdot m$ , you can solve for the molality of the unknown salt in water.

$$m = \frac{0.657}{3 \cdot 0.512}$$

$$m = 0.4277 \text{ mol kg}^{-1}$$

Then convert molality into moles by multiplying by the mass of the  $\text{H}_2\text{O}$  solvent:

$$\frac{0.4277 \text{ mol}}{\text{kg}} \left( \frac{0.2494 \text{ kg}}{1} \right) = 0.1067 \text{ mol}$$

Finally, we can use the gram quantity and number of moles to solve for the molecular weight of the salt:

$$\frac{19.7 \text{ g}}{0.1067 \text{ mol}} = 185 \text{ g/mol}$$

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**007 10.0 points**

Barium fluoride ( $\text{BaF}_2$ ) is most soluble in which of the following solutions?

- 0.50 M NaF
- 0.005 M  $\text{Ba}(\text{OH})_2$  **correct**
- 0.18 M NaF
- The molar solubility of barium fluoride is the same in each of these solutions
- 0.15 M  $\text{Ba}(\text{OH})_2$

**Explanation:**

According to the common ion effect, solubility decreases as the effective concentration of a common ion increases. The smallest common ion concentration would be the 0.005 M  $\text{Ba}(\text{OH})_2$ .

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**008 10.0 points**

Consider the following substances: acetic acid ( $\text{CH}_3\text{COOH}$ ), propane ( $\text{C}_3\text{H}_8$ ), and acetone ( $\text{CH}_3\text{COCH}_3$ ). The boiling points (in no particular order) are  $-42^\circ\text{C}$ ,  $56^\circ\text{C}$ , and  $118^\circ\text{C}$ . The vapor pressures (in no particular order) are 225 Torr, 15 Torr, and 6400 Torr. What is

the boiling point and vapor pressure for acetic acid?

- $118^\circ\text{C}$ , 15 Torr **correct**
- $56^\circ\text{C}$ , 225 Torr
- $-42^\circ\text{C}$ , 15 Torr
- $-42^\circ\text{C}$ , 6400 Torr
- $118^\circ\text{C}$ , 6400 Torr

**Explanation:**

Of the three compounds listed, acetic acid has the strongest IMFs (hydrogen bond). This will correspond to the lowest vapor pressure and highest boiling point: 15 Torr and  $118^\circ\text{C}$ .

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**009 10.0 points**

What is the ratio of potassium acetate to acetic acid necessary to make a buffer with a pH equal to 5.12?

- 2.4 **correct**
- 3.1
- 0.38
- 0.42
- 2.9
- 9.86

**Explanation:**

You can solve for the ratio using the H-H equation and knowledge of log rules:

$$\text{pH} = \text{p}K_a + \log \left( \frac{[\text{A}^-]}{[\text{HA}]}\right)$$

$$5.12 = 4.74 + \log \left( \frac{[\text{A}^-]}{[\text{HA}]}\right)$$

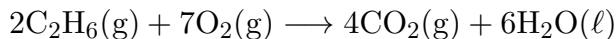
$$10^{5.12-4.74} = \frac{[\text{A}^-]}{[\text{HA}]}$$

$$= 2.4$$

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**010 10.0 points**

Consider the following reaction:



Oxygen is being consumed at a rate equal to 1.24 M/s. What is the initial rate at which carbon dioxide is forming?

1. 1.24 M/s
2. 4.96 M/s
3. 0.709 M/s **correct**
4. 8.68 M/s
5. 2.17 M/s

**Explanation:**

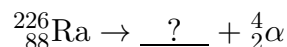
The stoichiometric ration between carbon dioxide and oxygen is 4:7. This means that carbon dioxide is being formed at  $\frac{4}{7}$  the initial rate of oxygen.

$$1.24 \text{ M/s} \times \frac{4 \text{ CO}_2}{7 \text{ O}_2} = 0.709 \text{ M/s}$$

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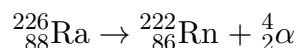
**011 10.0 points**

Identify the missing isotope in the nuclear reaction.



1.  ${}^{222}_{86}\text{Rn}$  **correct**
2.  ${}^{226}_{86}\text{Rn}$
3.  ${}^{230}_{86}\text{Th}$
4.  ${}^{230}_{90}\text{Th}$
5.  ${}^{222}_{90}\text{Rn}$

**Explanation:**




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**012 10.0 points**

What is the pH after 250 mL of 0.25 M  $\text{HNO}_3$  is added to 350 mL of 0.50 M  $\text{CH}_3\text{NH}_2$  (methylamine) ?

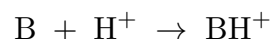
1. 3.36
2. 10.90 **correct**
3. 10.64
4. 6.21
5. 2.29
6. 10.38
7. 3.62
8. 5.05

**Explanation:**

This is a simple Henderson-Hasselbach calculation.

$$\text{pH} = \text{p}K_a + \log\left(\frac{C_B}{C_{\text{BH}^+}}\right)$$

The  $\text{p}K_b$  for methylamine (the base, B) is 3.36 which means the  $\text{p}K_a$  for the methylammonium ion ( $\text{BH}^+$ ) is 10.64. You may use the ratio of moles because this is a partial neutralization (buffer) problem. The weak base methylamine, B, is converted to the conjugate acid,  $\text{BH}^+$  via the reaction with the strong acid.



The acid is the limiting reactant and determines the amount of  $\text{BH}^+$  made. Remember, volume times concentration equals amount (moles).

$$\text{mol BH}^+ = 0.25(0.250) = 0.0625 \text{ mol}$$

$$\text{mol B} = .50(0.350) - 0.0625 \text{ mol} = .1125 \text{ mol}$$

Now solve for pH using the H-H equation:

$$\text{pH} = 10.64 + \log\left(\frac{0.1125}{0.0625}\right)$$

$$\text{pH} = 10.64 + 0.26$$

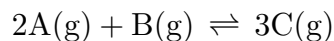
$$\text{pH} = 10.90$$

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**013 10.0 points**

0.834 atm A, 0.565 atm B, and 1.24 atm C are

placed into a container to run the following reaction:



At equilibrium, 0.435 atm C remains. What is  $K_p$  for this reaction?

- 18.8
- 0.0526 **correct**
- 0.107
- 0.0230
- 8.12

**Explanation:**

The first thing to observe in this question is that the reaction runs in reverse, because C is consumed over the course of the reaction. Running a RICE table, you will see that the change in C is equal to  $-3x = 0.435 - 1.24 = -0.805$ ; therefore,  $x = 0.2683$ .

$$P_A = 0.834 + 2x = 1.37067$$

$$P_B = 0.565 + x = .83333$$

Now you can solve for the equilibrium constant,  $K_p$ :

$$K_p = \frac{0.435^3}{1.37067^2 \cdot .83333} = 0.05258$$

**014 10.0 points**

A weak acid, HA, ionizes 7.65% at a 0.250 M concentration. What is the hydroxide ion concentration in this solution?

- $1.00 \times 10^{-14}$  M
- $1.91 \times 10^{-2}$  M
- $5.23 \times 10^{-13}$  M **correct**
- $1.31 \times 10^{-13}$  M
- $1.91 \times 10^{-16}$  M

**Explanation:**

Percent ionization quickly gives you the dissociation of a weak electrolyte at a particular

concentration:

$$[H^+] = 0.0765 \times 0.25 \text{ M}$$

$$[H^+] = 0.019125 \text{ M}$$

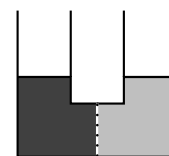
Use  $K_w$  to convert this into  $[OH^-]$ :

$$[OH^-] = \frac{1 \times 10^{-14}}{0.019125 \text{ M}}$$

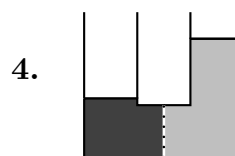
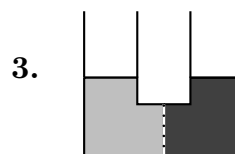
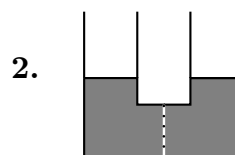
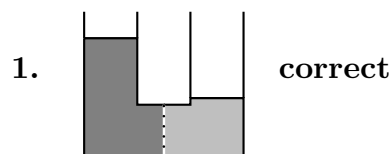
$$[OH^-] = 5.23 \times 10^{-13} \text{ M}$$

**015 10.0 points**

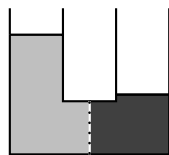
The following diagram shows a solution on the left (dark shade) and just the solvent on the right (light shade) separated by a semipermeable membrane.



Which diagram best represents the final state of this system after equilibrium is achieved?



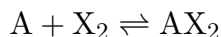
5.

**Explanation:**

Only the solvent goes through the membrane thus increasing the volume on the solution side and decreasing volume on the solvent side. The solution side is therefore diluted slightly and the shade is lightened somewhat. The solute itself (the darker color) cannot pass through the membrane so the right side MUST also stay the same color of pure solvent (the lightest shade shown).

**016 (part 1 of 2) 10.0 points**

You run an experiment to determine the initial rates of the following generic reaction at various starting conditions:



	[A] M	[X <sub>2</sub> ] M	initial rate M · s <sup>-1</sup>
Trial 1	0.60	1.56	2.00 × 10 <sup>-3</sup>
Trial 2	0.60	3.12	8.00 × 10 <sup>-3</sup>
Trial 3	1.20	1.56	4.00 × 10 <sup>-3</sup>
Trial 4	0.90	2.40	7.10 × 10 <sup>-3</sup>

What is the correct rate law for the reaction?

1. Rate = (3.84 × 10<sup>-3</sup>)[A]<sup>-1</sup>[X<sub>2</sub>]<sup>2</sup>
2. Rate = (1.40)[A]
3. Rate = (1.37 × 10<sup>-3</sup>)[A][X<sub>2</sub>]
4. Rate = (3.84 × 10<sup>-3</sup>)[A][X<sub>2</sub>]<sup>2</sup>
5. Rate = (1.37 × 10<sup>-3</sup>)[A][X<sub>2</sub>]<sup>2</sup> **correct**

**Explanation:**

Begin with the equation:

$$\text{Rate} = k[A]^x[B]^y$$

Compare trials to determine the value of  $x$  and  $y$ . Two good comparisons are trials 1 and 2 and trials 1 and 3.

Between trials 1 and 2, the concentration of X<sub>2</sub> doubles and the rate quadruples. Therefore,  $y = 2$ , meaning the reaction is second order in X<sub>2</sub>.

Between trials 1 and 3, [A] doubles and the rate doubles. This means  $x = 1$  and the reaction is first order in A.

Lastly, you can solve for  $k$  using any trial:

$$2.00 \times 10^{-3} = (1.37 \times 10^{-3})(0.60)(1.56)^2$$

**017 (part 2 of 2) 10.0 points**

What are the units of the rate constant in the previous question?

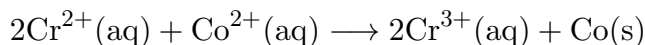
1.  $\frac{1}{M^3 \cdot s}$
2.  $\frac{1}{M \cdot s}$
3.  $\frac{M}{s}$
4.  $\frac{1}{M^2 \cdot s}$  **correct**
5.  $\frac{1}{M^4 \cdot s}$

**Explanation:**

The rate constant has units that cancel out the concentrations in the rate law to give a rate in M/s. The rate constant has units of  $\frac{1}{M^2 \cdot s}$

**018 (part 1 of 2) 10.0 points**

What is the shorthand notation for the following electrochemical cell?



1. Cr<sup>2+</sup> | Cr<sup>3+</sup> || Co<sup>2+</sup> | Co
2. Cr<sup>2+</sup> , Cr<sup>3+</sup> || Co<sup>2+</sup> | Co
3. Pt | Cr<sup>2+</sup> , Cr<sup>3+</sup> || Co<sup>2+</sup> | Co **correct**
4. Co | Co<sup>2+</sup> || Cr<sup>2+</sup> , Cr<sup>3+</sup> | Pt

**Explanation:**

You must use an inert electrode in the chromium solution compartment because you do not have a solid metal anode. Otherwise, follow your convention of: anode—*anodic* solution—*cathodic* solution—cathode

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**019 (part 2 of 2) 10.0 points**

What is the oxidizing agent in the previous problem?

1.  $\text{Co}^{2+}$  **correct**
2. Pt
3.  $\text{Cr}^{3+}$
4. Co
5.  $\text{Cr}^{2+}$

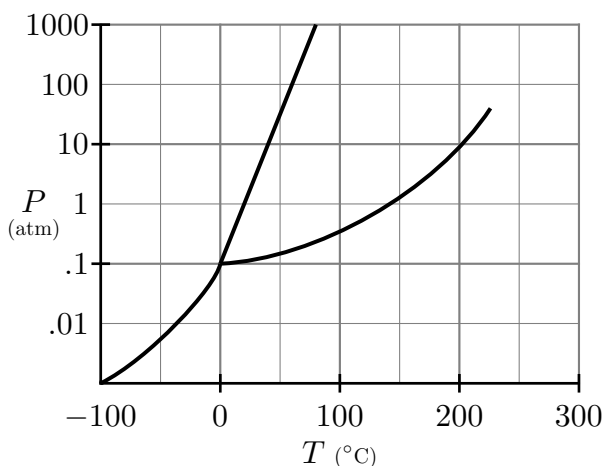
**Explanation:**

The oxidizing agent is the species being reduced. This is  $\text{Co}^{2+}$ .

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**020 (part 1 of 2) 10.0 points**

Use the following phase diagram for the next two questions.



What is the normal melting point for this substance? Note: the vertical axis is logarithmic in scale.

1.  $0^\circ\text{C}$

2.  $150^\circ\text{C}$

3.  $75^\circ\text{C}$

4.  $120^\circ\text{C}$

5.  $20^\circ\text{C}$  **correct**

6.  $45^\circ\text{C}$

**Explanation:**

The normal melting point is the point on the line where the solid and liquid phases coincide at 1 atm. This is found just less than halfway between the 0 and  $50^\circ\text{C}$  gridlines.

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**021 (part 2 of 2) 10.0 points**

A sample of this substance is held at 0.1 atm and  $-50^\circ\text{C}$ . The sample is pressurized to 3 atm and then heated to  $250^\circ\text{C}$ . In total, what phase transitions occurred?

1. melting and boiling **correct**
2. sublimation and condensation
3. melting and condensation
4. sublimation only
5. melting and freezing

**Explanation:**

Pressurizing from 0.1 atm to 3 atm does not result in a change of phase. However, heating to  $250^\circ\text{C}$  results in the melting of the solid followed by the vaporization of the liquid.

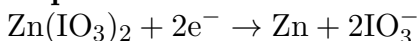
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**022 10.0 points**

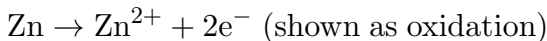
Use half-reactions from the standard reduction table to calculate the  $K_{\text{sp}}$  for  $\text{Zn}(\text{IO}_3)_2$ .

1.  $3.9 \times 10^{-6}$  **correct**
2.  $4.8 \times 10^{-12}$
3.  $1.7 \times 10^{-26}$
4.  $6.8 \times 10^{-32}$

$$5. 7.3 \times 10^{-19}$$

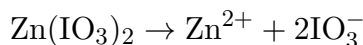
**Explanation:**

$$E^\circ = -0.922 \text{ V}$$



$$E^\circ = +0.762 \text{ V}$$

Adding the half-reactions together, we get the solubility reaction for  $\text{Zn}(\text{IO}_3)_2$ :



$$E^\circ = -0.922 + 0.762 = -0.160 \text{ V}$$

$K$  for this reaction then will be  $K_{\text{sp}}$  for  $\text{Zn}(\text{IO}_3)_2$ .

$$\begin{aligned} K_{\text{sp}} &= 10^{\frac{nE^\circ}{0.05916}} \\ &= 10^{\frac{(2)(-0.16)}{0.05916}} = 3.9 \times 10^{-6} \end{aligned}$$

**023 10.0 points**

$^{123}\text{I}$  is a radioactive isotope ( $t_{1/2} = 13.22$  hours) useful for clinical imaging. How long will it take for a dose to diminish to 18.7% of its original value?

- 34.2 hours
- 557 hours
- 38.7 hours
- 87.9 hours
- 70.7 hours
- 29.7 hours
- 22.2 hours
- 32.0 hours **correct**

**Explanation:**

This is radioactive decay, meaning we must follow first-order kinetics:

$$\ln\left(\frac{100}{18.7}\right) = kt$$

Solve for  $k$  first:

$$k = \frac{\ln(2)}{13.22 \text{ hours}}$$

$$k = 0.052431708 \text{ hours}^{-1}$$

Now complete the equation up top to solve for  $t$ :

$$\ln\left(\frac{100}{18.7}\right) / 0.052431708 \text{ hours}^{-1} = t$$

$$t = 32.0 \text{ hours}$$

**024 10.0 points**

Which of the following salts is the most soluble in pure water?

- CuBr  $K_{\text{sp}} = 6.3 \times 10^{-9}$
- CaF<sub>2</sub>  $K_{\text{sp}} = 3.5 \times 10^{-11}$  **correct**
- BaSO<sub>4</sub>  $K_{\text{sp}} = 1.1 \times 10^{-10}$
- All of these salts have the same solubility

**Explanation:**

Calculate the molar solubility,  $x$ , for each substance:

$$\text{CaF}_2: K_{\text{sp}} = 3.5 \times 10^{-11} = 4x^3$$

$$x = 2.06 \times 10^{-4} \text{ (correct)}$$

$$\text{BaSO}_4: K_{\text{sp}} = 1.1 \times 10^{-10} = x^2$$

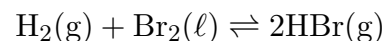
$$x = 1.05 \times 10^{-5}$$

$$\text{CuBr}: K_{\text{sp}} = 6.3 \times 10^{-9} = x^2$$

$$x = 7.94 \times 10^{-5}$$

**025 10.0 points**

Write the equilibrium constant for the following reaction.



$$1. K_p = \frac{P_{\text{HBr}}^2}{P_{\text{H}_2}}$$

**correct**

$$2. K_p = \frac{P_{\text{HBr}}^2}{P_{\text{H}_2}[\text{Br}_2]}$$



$$3. K_p = \frac{P_{\text{H}_2}}{P_{\text{HBr}}^2}$$

$$4. K_p = \frac{P_{\text{HBr}}}{P_{\text{H}_2}}$$

$$5. K_p = \frac{P_{\text{HBr}}^2}{P_{\text{H}_2} P_{\text{Br}_2}}$$

**Explanation:**

Take the concentration of the products raised to the power of their coefficients divided by the reactants raised to the power of their coefficients, ignoring any liquid or solids.

$$K_p = \frac{P_{\text{HBr}}^2}{P_{\text{H}_2}}$$

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**026 10.0 points**

A sample of 44.1 g of *para*-dichlorobenzene ( $\text{C}_6\text{H}_4\text{Cl}_2$  147.0 g/mol) is dissolved into 350 mL of hexane ( $\text{C}_6\text{H}_{14}$ , 86.18 g/mol, density 0.661 g/mL). What is the molality of this solution?

1. 1.30 *m* **correct**

2. 0.101 *m*

3. 0.857 *m*

4. 1.17 *m*

5. 0.567 *m*

**Explanation:**

Molality is defined as the moles of solute divided by kg solvent. Solve first for the mass of solvent:

$$350 \text{ mL} \times \frac{0.661 \text{ g}}{\text{mL}} = 231.35 \text{ g}$$

mol of solute =  $44.1/147 = 0.300$  mol solute  
Next take the ratio of moles solute per kg solvent:

$$\frac{0.300 \text{ mol}}{0.23135 \text{ kg}} = 1.2967 = 1.30 \text{ m}$$

---

**027 10.0 points**

Calculate the number of moles of oxygen that will dissolve in 45 L of water at 20°C if the partial pressure of oxygen is 0.21 atm. The Henry's Law constant for oxygen in water at 20°C is 0.0013 M/atm.

1. 0.0062 mol

2. 0.00027 mol

3. 0.0013 mol

4. 0.28 mol

5. 0.012 mol **correct**

**Explanation:**

---

**028 10.0 points**

What is the pH of a 0.12 M solution of hydroxylammonium bromide ( $\text{NH}_3\text{OHBr}$ )?

1. 4.44

2. 3.24

3. 3.33

4. 3.61

5. 9.56

6. 3.48 **correct**

7. 3.72

8. 6.04

**Explanation:**

$$M_{\text{NH}_3\text{OHBr}} = 0.12 \text{ M} \quad K_b = 1.1 \times 10^{-8}$$

It's a salt of a weak base (BHX). This means you need a  $K_a$  for the weak acid  $\text{BH}^+$ . Use  $K_a = \frac{K_w}{K_b}$  and you'll get the  $K_a = 9.09091 \times 10^{-7}$ . You CAN use the approximation for the equilibrium which means that

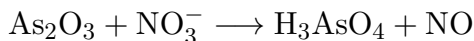
$$[\text{H}^+] = \sqrt{K_a \cdot C_{\text{BH}^+}} = 0.000330289 \text{ M}$$

$$\text{pH} = -\log(0.000330289) = 3.48111$$

---

**029 10.0 points**

The following reaction occurs in acidic conditions. What is the coefficient of water in the overall balanced equation? Is it a reactant or a product?



1. 3; reactant
2. 7; reactant **correct**
3. 2; product
4. 4; reactant
5. 2; reactant
6. 3; product

**Explanation:**

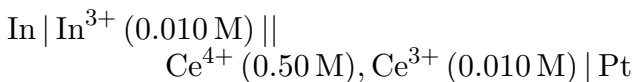
The correctly balanced equation is:  

$$7\text{H}_2\text{O} + 4\text{H}^+ + 3\text{As}_2\text{O}_3 + 4\text{NO}_3^- \longrightarrow 6\text{H}_3\text{AsO}_4 + 4\text{NO}$$

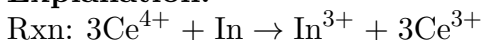
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**030 10.0 points**

What is the potential for the following cell?



1. 2.37 V
2. 1.88 V
3. 2.02 V
4. 1.95 V
5. 1.81 V
6. 2.09 V **correct**

**Explanation:**

$$E^\circ = 1.61 - (-0.34) = 1.95 \text{ V}$$

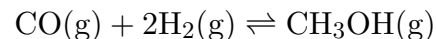
$$Q = \frac{[\text{Ce}^{3+}]^3[\text{In}^{3+}]}{[\text{Ce}^{4+}]^3} = \frac{(0.01)^3(0.01)}{(0.5)^3} = 8.0 \times 10^{-8}$$

$$E = 1.95 - \frac{0.05916}{3} \log(8.0 \times 10^{-8}) = 2.09 \text{ V}$$

---

**031 (part 1 of 2) 10.0 points**

Consider the following reaction for the next two questions:



Beginning at equilibrium, which of the following will result in a shift toward the right of this reaction?

1. Adding an inert gas at constant volume
2. Adding an inert gas at constant pressure
3. Adding  $\text{CH}_3\text{OH}$  gas
4. Removing  $\text{CO}$  gas
5. Reducing the volume of the container **correct**

**Explanation:**

The only option that will cause a shift to the right of this reaction is reducing the volume of the container. By reducing the volume of the container, the pressure is increased. Increasing the overall pressure results in a shift way from the side of the reaction with the most gas moles.

---

**032 (part 2 of 2) 10.0 points**

If this reaction is exothermic, lowering the temperature will cause the reaction to...

1. remain at equilibrium
2. shift right due to a larger  $K$  value **correct**
3. shift left due to a smaller  $K$  value
4. shift left due to a smaller  $Q$  value
5. shift right due to a decreased  $Q$  value

**Explanation:**

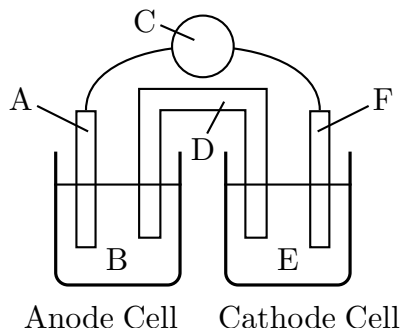
Reducing the temperature of an exothermic reaction will cause the reaction to shift to

the right. This is because an exothermic reaction will have a larger  $K$  value when the temperature is decreased.

---

**033 (part 1 of 2) 10.0 points**

The following two questions refer to this diagram for a voltaic cell. Neither of the two electrodes are an inert electrode.



Where would you find the species that is being oxidized?

1. D
2. C
3. B
4. A **correct**
5. E

**Explanation:**

A is the electrode in the anode cell. Oxidation always occurs at the anode.

---

**034 (part 2 of 2) 10.0 points**

If the half-reaction for the anode involves  $\text{Fe}^{2+}$  and Fe, which of these redox pairs could be in the cell on the right?

1.  $\text{H}^+$  and  $\text{H}_2$
2. None of these can give a voltaic cell
3.  $\text{Cr}^{3+}$  and Cr
4.  $\text{Sn}^{2+}$  and Sn **correct**
5.  $\text{Mn}^{2+}$  and Mn

**Explanation:**

Because the  $\text{Fe}^{2+}/\text{Fe}$  half-reaction is the anode and this is a galvanic cell, the other half-reaction must have a standard reduction potential that is more positive (higher up on the standard reduction potential table) than that of  $\text{Fe}^{2+}/\text{Fe}$ . Only two answer choices have a more positive reduction potential:  $\text{Sn}^{2+}/\text{Sn}$ , and  $\text{H}^+/\text{H}_2$ . But the  $\text{H}^+/\text{H}_2$  half-reaction has no solid component to serve as an electrode and therefore requires a platinum electrode, and the problem specifies that there are no platinum electrodes. That leaves  $\text{Sn}^{2+}/\text{Sn}$  as the only option.

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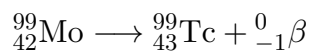
**035 10.0 points**

$^{99}_{42}\text{Mo}$  undergoes radioactive decay by emitting a single beta particle. Which of the following reactions corresponds to this process?

1.  $^{99}_{42}\text{Mo} \rightarrow ^{99}_{43}\text{Tc} + ^0_{-1}\beta$  **correct**
2.  $^{99}_{42}\text{Mo} + ^0_{-1}\beta \rightarrow ^{99}_{41}\text{Nb}$
3.  $^{99}_{42}\text{Mo} + ^0_{-1}\beta \rightarrow ^{99}_{43}\text{Tc}$
4.  $^{99}_{42}\text{Mo} \rightarrow ^{99}_{44}\text{Ru} + ^0_{-1}\beta$
5.  $^{99}_{42}\text{Mo} \rightarrow ^{98}_{42}\text{Tc} + ^1_0n$

**Explanation:**

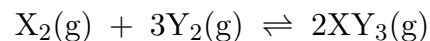
Write the balanced reaction involving the emission of a  $^0_{-1}\beta$  particle.




---

**036 10.0 points**

Consider the following generic gas phase reaction.



The value of  $K_p$  for this reaction is 107. Calculate the equilibrium partial pressure of gas  $\text{Y}_2$  if the equilibrium partial pressures of  $\text{XY}_3$  is 0.50 atm and  $\text{X}_2$  is 0.15 atm?

1. 5.6 atm
2. 0.33 atm
3. 0.016 atm

4. 0.42 atm

5. 0.031 atm

6. 0.25 atm **correct**

7. 0.18 atm

**Explanation:**

$$107 = K_p$$

$$107 = \frac{(P_{XY_3})^2}{(P_{X_2})(P_{Y_2})^3} = \frac{(0.50)^2}{(0.15)(P_{Y_2})^3}$$

$$P_{Y_2} = 0.25 \text{ atm}$$

**037 10.0 points**

Isocarboxazid (MW = 231.25 g/mol) is an organic monoamine oxidase inhibitor used to treat depression disorders. 38.00 grams of isocarboxazid are added to water to make a 350 mL aqueous solution. What is the osmotic pressure exerted by this solution across a semi-permeable membrane at 37°C?

1. 12.10 atm

2. 329.6 atm

3. 23.90 atm

4. 1.43 atm

5. 144.4 atm

6. 11.95 atm **correct****Explanation:**

Osmotic pressure is calculated using the formula:

$$\Pi = MRT$$

$$R = 0.08206 \text{ L} \cdot \text{atm}/\text{mol} \cdot \text{K}$$

$$T = 310.15 \text{ K}$$

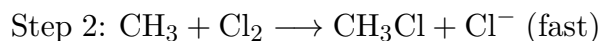
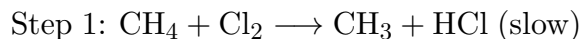
Solving first for molarity:

$$M = \frac{(38.0 \text{ g})\left(\frac{\text{mol}}{231.25 \text{ g}}\right)}{0.350 \text{ L}} = 0.4695 \text{ M}$$

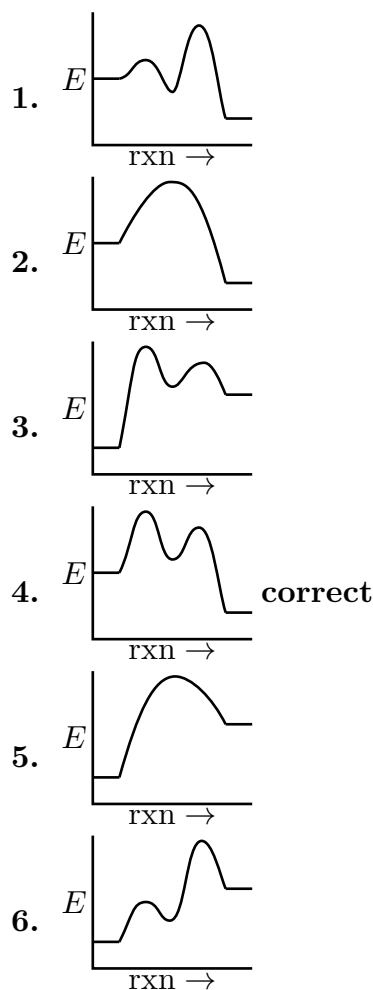
$$11.95 \text{ atm} = (0.4695)(0.08206)(310.15)$$

**038 10.0 points**

The chlorination of methane is an exothermic reaction with a two-step mechanism shown below:



Which of the following reaction coordinate diagrams best fits this data?

**Explanation:**

The reaction coordinate diagram should match the mechanism and thermodynamics of the reaction. The reaction profile is exothermic, has two humps, and the first hump should be the largest (rate-determining step).

**039 10.0 points**

Rank the following acids in increasing order of acidity.



1.  $\text{HCN} < \text{NH}_3\text{OH}^+ < \text{HNO}_2 < \text{HBrO}$
2.  $\text{NH}_3\text{OH}^+ < \text{HBrO} < \text{HCN} < \text{HNO}_2$
3.  $\text{HNO}_2 < \text{NH}_3\text{OH}^+ < \text{HBrO} < \text{HCN}$
4.  $\text{HNO}_2 < \text{HBrO} < \text{HCN} < \text{NH}_3\text{OH}^+$
5.  $\text{NH}_3\text{OH}^+ < \text{HNO}_2 < \text{HBrO} < \text{HCN}$
6.  $\text{HCN} < \text{HBrO} < \text{NH}_3\text{OH}^+ < \text{HNO}_2$  **correct**

**Explanation:**

Look at the coversheet for the values of  $pK_a$ .

$$\text{HCN} = 9.21$$

$$\text{NH}_3\text{OH}^+ = 14 - 7.96 = 6.04$$

$$\text{HNO}_2 = 3.40$$

$$\text{HBrO} = 8.20$$

**040 10.0 points**

Calculate the pH of a 0.018 M  $\text{Ba}(\text{OH})_2$  solution.

1. 5.26
2. 8.44
3. 12.56 **correct**
4. 12.26
5. 1.44
6. 1.74

**Explanation:**

0.018 M  $\text{Ba}(\text{OH})_2$  is a strong base that dissociates completely, resulting in a 0.036 M hydroxide ion concentration.

$$\text{pOH} = -\log(0.036 \text{ M})$$

$$\text{pH} = 14 - \text{pOH} = 12.56$$

**041 10.0 points**

How does a catalyst affect the rate of a chemical reaction?

1. A catalyst increases the rate constant by increasing the activation energy
2. A catalyst increases the energy of the transition state such that a larger number of particles have sufficient energy to overcome the activation energy
3. A catalyst increases the rate constant by providing an alternate mechanism with a lower activation energy **correct**
4. A catalyst decreases the rate constant by lowering the activation energy

**Explanation:**

A catalyst increases the rate constant by providing an alternate mechanism with a lower activation energy

**042 10.0 points**

When direct heat is applied to potassium chlorate,  $\text{KClO}_3$ , it decomposes to form  $\text{KCl}$  and other byproducts. Was chlorine oxidized or reduced? How many electrons were transferred during the process?

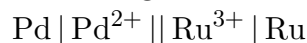
1. oxidized, 3 electrons
2. reduced, 9 electrons
3. oxidized, 6 electrons
4. oxidized, 4 electrons
5. reduced, 3 electrons
6. reduced, 6 electrons **correct**

**Explanation:**

For the conversion of  $\text{KClO}_3$  to  $\text{KCl}$ , the Cl atom is going from a +5 to a -1 oxidation state. This is a reduction reaction that involves the gain of 6 electrons.

**043 10.0 points**

Consider the following cell:



What is  $\Delta G^\circ$  for the overall cell reaction that is represented here? Balance the reaction using the lowest possible integer values.

1.  $-91.2 \text{ kJ}$
2.  $+91.2 \text{ kJ}$
3.  $+877 \text{ kJ}$
4.  $+182 \text{ kJ}$  **correct**
5.  $-877 \text{ kJ}$
6.  $-182 \text{ kJ}$

**Explanation:**

$$\text{Pd}^{2+}/\text{Pd} = +0.915 \text{ V}$$

$$\text{Ru}^{3+}/\text{Ru} = +0.60 \text{ V}$$

$$E^\circ = 0.60 - 0.915 = -0.315 \text{ V}$$

$$\Delta G^\circ = -nFE^\circ$$

$$= -6(96485)(-0.315) = +182356 \text{ J}$$

$$= +182 \text{ kJ}$$

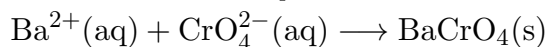
#### 044 10.0 points

What is the mass of the barium chromate precipitate resulting from the addition of 300 mL 0.025 M  $\text{Ba}(\text{OH})_2$  to 200 mL 0.040 M  $\text{Na}_2\text{CrO}_4$ ?

1. 1.90 g **correct**
2. 3.80 g
3. 2.03 g
4. 2.52 g
5. 3.48 g

**Explanation:**

Start with the relevant net ionic formula based on what was provided in the question stem (Note: you can confirm that a precipitate will form using  $Q_{\text{sp}}$ ):



Here you should see that this is a limiting reagent problem. Because barium chromate has a very small  $K_{\text{sp}}$ , it is safe to assume the reaction goes approximately 100%. Solve for moles of each reagent:

$$\text{Ba}^{2+} : 0.0250 \text{ M} \times 0.300 \text{ L} = 0.00750 \text{ mol}$$

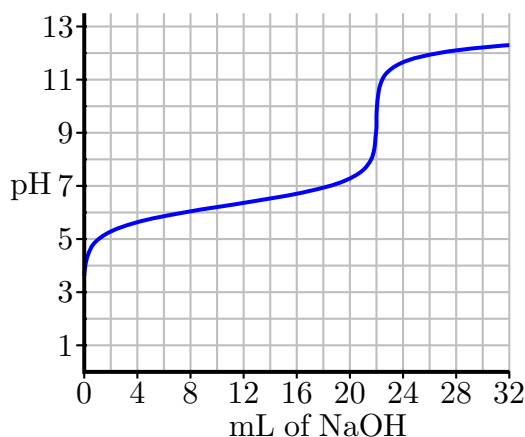
$$\text{CrO}_4^{2-} : 0.0400 \text{ M} \times 0.200 \text{ L} = 0.00800 \text{ mol}$$

This reaction is 1:1:1, so you can determine that the limiting reagent is the reactant with the fewest number of moles. This is also the number of moles of product formed. Convert to mass:

$$0.00750 \times 253.37 \text{ g/mol} = 1.90 \text{ g}$$

#### 045 (part 1 of 3) 10.0 points

A sample of 30 mL of a weak acid (HA) solution was titrated with 0.075 M NaOH. The pH curve for this titration is shown.

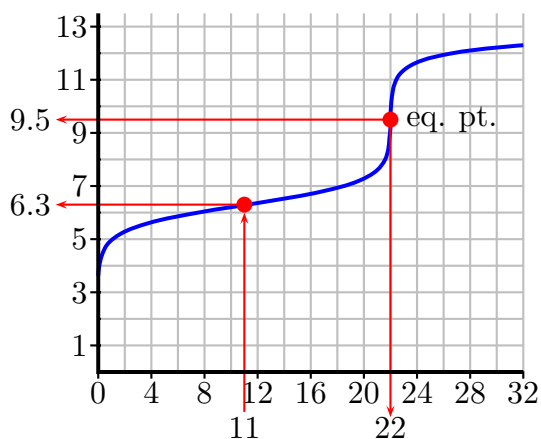


What is the concentration of the original weak acid solution (the 30 mL) ?

1. 0.075 M
2. 0.055 M **correct**
3. 0.032 M
4. 0.048 M

5. 0.022 M

**Explanation:**



equivalence point is 22 mL of NaOH  
 $\times 0.075 \text{ M} = 1.65 \text{ mmol OH}^-$   
 $\text{mmol acid} = \text{mmol base}$   
 $1.65 \text{ mmol} / 30 \text{ mL} = 0.055 \text{ M HA}$

---

**046 (part 2 of 3) 10.0 points**

Which of the following is the value of  $K_a$  for the weak acid, HA ?

- $1.2 \times 10^{-7}$
- $5.0 \times 10^{-7}$  **correct**
- $1.3 \times 10^{-6}$
- $7.6 \times 10^{-5}$
- $3.2 \times 10^{-10}$

**Explanation:**

The half titration point is at 11 mL and the  $\text{pH} = \text{pK}_a$  there which is 6.3. That would match a  $K_a$  of  $5.0 \times 10^{-7}$ .

---

**047 (part 3 of 3) 10.0 points**

Below is a listing of five indicators and their associated  $\text{pK}_a$  values. Which indicator would be the best one to use for this titration?

- bromocresol purple, 6.4
- methyl red, 5.0

3. thymol blue, 9.3 **correct**

4. bromophenol blue, 4.1

5. phenol red, 7.4

6. alizarin yellow, 10.9

**Explanation:**

The equivalence point is at a pH of 9.5. Only thymol blue in this listing covers that pH during the color transition.

---

**048 10.0 points**

You mix 0.02 mmol  $\text{Sr}(\text{NO}_3)_2$  solution and 0.05 mmol NaF solution to form a 100 mL solution. What precipitate (if any) forms?

- $\text{NaNO}_3$
- $\text{Sr}(\text{NO}_3)_2$
- NaF
- $\text{SrF}_2$
- No precipitate forms **correct**

**Explanation:**

First, come up with the double-displacement equation for this problem to show that  $\text{SrF}_2$  is the solid product. However, this product will only be formed if  $Q > K$ . Therefore, you must solve for  $Q_{\text{sp}}$  at the instant of mixing:

$$Q_{\text{sp}} = [\text{Sr}^{2+}][\text{F}^-]^2$$

$$Q_{\text{sp}} = (.0002)(0.0005)^2 = 5.11 \times 10^{-11}$$

Compare to  $K_{\text{sp}}$ , which is  $4.3 \times 10^{-9}$ . Because  $Q$  is less than  $K$ , the solution is under-saturated and no precipitate forms.

---

**049 10.0 points**

The enthalpy of vaporization of a liquid is measured to be about 28.4 kJ/mol and its normal boiling point is  $128^\circ\text{C}$ . At what temperature is the partial pressure of this substance 1180 torr?

- $176^\circ\text{C}$

they are equal to zero (think of this voltaic cell as a dead battery).

2. 150°C **correct**

3. -281°C

4. 181°C

5. 162°C

6. -381°C

7. -7.92°C

**Explanation:**

Here we use the Clausius-Clapeyron equation to solve for  $T_1$ :

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{\text{vap}}}{R} \left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$P_1 = 1180 \text{ torr}$$

$$P_2 = 760 \text{ torr}$$

$$T_2 = 124^\circ\text{C} + 273 = 401 \text{ K}$$

$$\Delta H_{\text{vap}} = 28.4 \text{ kJ/mol}$$

$$R = 0.008314 \text{ kJ/mol K}$$

And...

$$T_1 = 150^\circ\text{C}$$

---

**050 10.0 points**

Consider a standard voltaic cell at equilibrium. Which of the following is true?

1.  $E > 0$ ,  $\Delta G > 0$ ,  $K > 1$

2.  $E < 0$ ,  $\Delta G > 0$ ,  $K < 0$

3.  $E < 0$ ,  $\Delta G > 0$ ,  $K < 1$

4.  $E = 0$ ,  $\Delta G = 0$ ,  $K = 1$

5.  $E = 0$ ,  $\Delta G = 0$ ,  $K > 1$  **correct**

**Explanation:**

For a voltaic cell at equilibrium:

$$E = 0, \Delta G = 0, K > 1$$

It is important to realize here that  $E$  and  $\Delta G$  are not standard values, so at equilibrium