Day 16: Answers and Explanations

Answers: Quick Check:

1. **B**	2. **D**	3. **A**	4. **E**	5. **B**	6. **B**	7. **E**	8. **C**	9. **A**	10. **C**
11. **E**	12. **A**	13. **B**	14. **A**	15. **D**	16. **D**	17. **C**	18. **C**	19. **E**	20. **B**
21. **D**	22. **C**	23. **E**	24. **A**	25. **C**	26. **C**	27. **E**	28. **B**	29. **C**	30. **C**
31. **E**	32. **C**	33. **C**	34. **D**	35. **C**	36. **D**	37. **E**	38. **C**	39. **E**	40. **D**
41. **A**	42. **A**	43. **C**	44. **B**	45. **D**	46. **E**	47. **E**	48. **C**	49. **B**	50. **D**

Answers and Explanations

Questions 1 through 5: interpreting phase change diagram

1. **B** *Note:* From Left to right of segment 1, temperature is increasing

Recall: As temperature increases, average kinetic energy increases.

2. **D** *Note:* Melting (solid to liquid) is taking place during segment 2.

Recall: Fusion is another term for melting.

3. **A** *Note:* The substance exists only as a liquid during segment 3

4. **E** *Note:* Boiling (liquid to gas) is taking place during segment 4.

Heat of vaporization is measured during boiling.

5. **B** *Note:* From Left to right of segment 5, temperature is increasing

Recall: As temperature increases, average kinetic energy increases.

6. **B** **Relating orbital notation to properties atom**

Note: The total number of electrons in this configuration is 4.

The atom is beryllium (Be), an alkaline earth metal.

Recall: Alkaline earth metals react with water to form bases as represented below.

Be + H_2O -----> $Be(OH)_2$ + H_2

alkaline earth — *water* — *base*

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7. **E** *Note:* The total number of electrons in this configuration is 26. The atom is Fe, a transition metal.

Recall: Transition metals form colored aqueous solutions

8. **C** *Note:* This configuration has 6 electrons. The atom is carbon (C)

Recall: A carbon atom readily forms four covalent bonds

9. **A** *Note:* This configuration has only 1 electron that is occupying a *higher sublevel.*

Recall: An atom that is not in the ground state (an excited state atom) has electron that had absorbed enough energy to jump to a higher energy level.

10. **C** **Properties of elements**

Note: Of the three metals; Na, Mg, and Al, Al has the greatest (heaviest) molecular mass (see Periodic Table)

11. **E** *Recall:* Electronegativity values (a measure of atom's ability to attract electrons from another atom during bonding) increases from left to right.

Note: Of all the elements listed, Cl (a halogen) if the farthest right, hence, the one that is most likely to attract electrons.

12. **A** *Recall:* Ionization energy (energy to remove the most loosely bound electron from an atom) decreases from right to left.

Note: Of all the elements listed, Na (an alkali metal) is the farthest left, hence, the one with the lowest ionization energy.

13. B *Note:* Of elements listed, Mg is the only atom with two electrons in its valance shell.

Note: The first and second ionization energies are energies to remove the first and second valance electron, respectively, and form a stable noble gas configuration

Note: The third ionization energy is, therefore, energy to remove an electron from a stable Mg atom. This energy will be much higher than the second ionization energy since a stable Mg atom (Mg^{2+}) will be unwilling to lose any more electron.

14. A *Note:* All the elements listed are in the same Period (3).

Recall: Atomic radius of elements in the same period decreases from left to right due to increase in nuclear charge (number of protons).

Note: Na is the farthest left of all the listed elements, hence, the one with the largest atomic radius.

15. D **Energy of electron**

Recall the equation below

$$E_n = \frac{-2.178 \times 10^{-18}}{n^2} \text{ joules}$$

For n = 4

$$E_n = \frac{\mathbf{-2.178 \times 10^{-18}}}{\mathbf{16}} \text{ joules}$$

16. D **hybrization and molecular shape**

Note: A d^2sp^3 hybridized molecule can have different shapes depending on the number of nonbonding electron pairs of the central atom

hybridization	*number of unbonded pair*	*shape*
d^2sp^3	0	Octahedral
d^2sp^3	1	square pyramidal
d^2sp^3	2	square planer

Note: d^2sp^3 can never produce a tetrahedral shape molecule.

17. C **molality calculation**

Assume 100 grams of the solution

Step 1: Determine mass of solvent and solute

mass of solute C_6H_2O = 10% of 100 g = 10 g C_6H_2O

Mass of solvent H_2O = 90% of 100 g = 90 g H_2O

Step 2: Determine moles of solute C_6H_2O

$$\text{moles} = \frac{\text{mass of } C_6H_2O}{\text{molar mass } C_6H_2O} = \frac{10\text{ g}}{90\text{ g/mol}^{-1}} = 0.11\text{ mol}$$

Step 3: Calculate molality (*m*)

$$m = \frac{\text{moles solute}}{\text{Kg solvent}} = \frac{0.11\text{ mol}}{0.090\text{ Kg}} = \mathbf{1.22\ m}$$

18. C **Polyatomic ion formulas**

Recall the symbols for the polyatomic ions given as choices

(A) Nitrate NO_3^-
(B) Sulfate SO_4^{2-}
(C) Phosphate $\mathbf{PO_4^{3-}}$ **(greatest – charge)**
(D) Permanganate MnO_4^-
(E) Ammonium NH_4^+

19. E **Lab safety**

Recall the following lab safety procedure:

Any spill onto skin should be washed with large amount of water

Note: Since the spill is a base, a dilute acid can also be use to further neutralize the base

Note: A strong acid like HCl should never be used on the skin, no matter how dilute its concentration.

20. B **Intermolecular forces**

Note: Carbon tetrachloride is a nonpolar substance because its molecules, CCl_4, are symmetrical.

Recall: London (aka dispersion) forces are intermolecular forces that hold nonpolar molecules together in the solid state.

21. D **Understanding galvanic cell components**

Recall: in a galvanic cell, electrons flow through the wire from the anode (oxidation site, where electrons are lost) to the cathode (reduction site, where electrons are gained)

Recall: The more active of the two metals is always the anode.

Note: According to the Standard Reduction Potential Table: Zn is more active (more easily oxidized) than Ni

Relate: Zn is the anode and Ni is the cathode. Electrons will always flow from anode (Zn) to cathode (Ni) through the wire.

22. C **Understanding galvanic cell reaction**

Note: Based on the diagram and information given:

The **oxidation-half** reaction is: Zn -------> Zn^{2+} + 2e-

The **reduction-half** reaction is: Ni^{2+} + 2e- ----> Ni

Add the two equations: Zn + Ni^{2+} ----> Zn^{2+} + Ni

23. E **Conjugate acid-base pair**

Recall: Formulas of a conjugate acid-base pair differ by just one H.

Note: H_3PO_4 and PO_4^{3-} are the only pair that differs by more than 1 H atom. Therefore, are NOT acid-base pair.

24. **A** **Percent composition by mass**

Note: The total mass of X must be 2.5 times greater than the total mass of O in the formula

Note: Only in choice A formula, XO, that this is the case

$$\frac{\text{Total mass of X}}{\text{Total mass of O}} = \frac{40\text{ g}}{16\text{ g}} = \frac{2.5}{1}$$

25. **C** **Significant figures**

Note: You are looking for a choice in which the answer has 4 significant figures

Recall the following rules for determining significant figures

When multiplying or dividing:

Limit or round the answer to the same number of significant figures as the factor with the least number of significant figures.

Eliminate Choice A: Answer will have 3 significant figures

Eliminate Choice B: Answer will have 5 significant figures

Eliminate Choice E: Answer will have 2 significant figures

When adding or subtracting:

Limit or round answer to the same number of decimal places as the factor with the least decimal places.

Eliminate Choice D: Answer will have 5 significant figures

Choice C: 0.023 + 1.311 = 1.334 (4 significant figs)

3 decimal places *3 decimal places* *3 decimal places*

26. C **Rutherford Gold Foil experiment, atomic structure**

Recall the following Gold Foil experiment conclusions made by Rutherford
. Atom is mostly unoccupied empty space
. Atom central core is more massive, denser, and smaller than the rest of the atom

27. E **Le Chatelier's principle, Solution Equilibrium , dissociation**

Step 1: Write the equilibrium equation to represent the ionization reaction described.

$Ag_2CO_3(s)$ <======> $2Ag^+(aq)$ + $CO_3^{2-}(aq)$

Note: The reaction favors ionization when the addition of the listed substance ***shift the reaction right*** (or produces more ions)

Step 2: Use your knowledge of reactions and Le Chatelier's principle to indicate what happens to the reaction when each substance is added.

(1) $AgNO_3$ added : ionizes into Ag^+: ↑ $[Ag^+]$ Reaction shifts Left
(2) **NH_3 added: forms $Ag(NH_3)^{2+}$ ↓ $[Ag^+]$ Reaction shifts Right**
(3) Na_2CO_3 added : ionizes into CO_3^{2-} : ↑$[CO_3^{2-}]$ Reaction shifts Left
(4) **HNO_3 added : H+ reacts with CO_3^{2-} ↓$[CO_3^{2-}]$ Reaction shifts Right**

Note: Only the addition of NH_3 (2) and HNO_3 (4) shift the reaction Right.

28. B **pH – acid concentration relationship**

Note: Acetic is a weak acid.

Where as a strong 0.1 molar acid will have a pH of 1 or 2, a weak 0.1 molar acid (like acetic) will have a pH higher than a 2, but less than 7. Choice B (pH 4) is in this range.

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29. C **Rate of change, reactant - product relationship**

W + X -------> Y + 2Z

Note: W and X are reactants.

Y and Z are products

Relate: The sign for the rate of change will be the same for W and X
The sign for the rate of change will be the same for Y and Z, but opposite that of W and X.

Eliminate Choice B and D because these are not the case.

Note: The mole ratio in the equation is **1**W : **1**X : **1**Y : **2**Z

Relate: The coefficients for rate of change with respect to W, X and Y must be a 1.

The coefficient for rate of change with respect to Z must be ½ or 0.5 since there are twice the number of moles of Z.

Choice C is correct because when all information are considered, the signs for rate of change and the coefficients of substances with respect to each other are all correct.

30. C **Half-life, order of decay reaction, data interpretation**

Note: Half-life of the radioisotope is **6 days** because this is when 50% (½) of it remains.

Recall: All radioactive decay is **First Order** because decay is independent of the initial concentration of the radioisotope.

31. E **Redox reaction interpretation, oxidation numbers**

Note: Oxidation numbers must be correctly assigned to the elements in the equation before the correct statement can be determined.

+2 **-3**	0	0	+1 -2	+1 +2 **-3**	-2 +1
8C**N**$^-$ +	4Ag +	O_2 +	$2H_2O$ ------>	$4Ag(C\mathbf{N})_2^-$ +	4 O H^-

cyanide ion

Note: Of the statements given as choices, only Choice E (N is -3 in the cyanide ion) is correct

32. **C** **Half-life, fraction remaining, nuclear decay**

Note: Percent of radioisotope remaining unchanged can be estimated using fraction remaining equation:

$$\text{Fraction remaining} = \left(\frac{1}{2}\right)^n$$

n = half-life periods
n = 11.5 / 6.93 ≈ 2

$$\text{Fraction remaining} = \left(\frac{1}{2}\right)^2 = \frac{1}{4} = 25$$

Note: Since all the choices are very far apart, the most reasonable estimated answer is Choice 3 (30%)

33. **C** **Spontaneity in physical and chemical changes**

Recall: Spontaneous processes occurs when the reaction leads to a state of higher entropy (increase disorder of the system)

Note: In Choice C, expansion of a gas (increase space/volume) is accompanied by increase in entropy because the gas particles can move even more freely (increase disorder)

34. **D** **Mass – mass calculation in equation, limiting reagent**

Note: To correctly calculated mass of Fe that can be produced, the limiting reagent in the reaction must be identified.

Step 1: Determine mass of C that will react with 500 g of Fe_2O_3 using mass and mole ratios in factor-labeling

$$500\text{ g }Fe_2O_3 \times \frac{1\text{ mole }Fe_2O_3}{160\text{ g }Fe_2O_3} \times \frac{3\text{ mol C}}{2\text{ mol }Fe_2O_3} \times \frac{12\text{ g C}}{1\text{ mol C}} = \mathbf{56\text{ g Fe}}$$

Note: Fe_2O_3 is the limiting reagent in the reaction because: According to the calculation, all 500 g of the Fe_2O_3 will be completely consumed when only 56 g of the 75 g of C is used up.

Step 2: Calculate mass of Fe using mole ratio of Fe_2O_3 to Fe

$$500\text{ g }Fe_2O_3 \times \frac{1\text{ mol }Fe_2O_3}{160\text{ g }Fe_2O_3} \times \frac{4\text{ mol Fe}}{2\text{ mol }Fe_2O_3} \times \frac{56\text{ g Fe}}{1\text{ mol Fe}} = \mathbf{350\text{ g Fe}}$$

35. **B** **Enthalpy, entropy, and volume changes of a phase change**

$H_2O(l)$ -------> $H_2O(s)$

Note: The change shown is freezing:

ΔH is – (exothermic) because heat is released as liquid freezes: $\mathbf{\Delta H < 0}$

ΔS is – (↓ entropy) because particles become more organized: $\mathbf{\Delta S < 0}$

ΔV is + (↑ volume) because water expands as it turns to ice: $\mathbf{\Delta V > 0}$

36. **C** **Interpreting potential energy diagram**

Note: A is reactant; C is product

Recall: Enthalpy (ΔH) = $H_{product} - H_{reactant}$

Enthalpy (ΔH) = **C – A**

37. E **Acid-base titration, neutralization**

Recall: Acid and abase will produce a neutral solution (pH = 7) when equal moles of H+ and OH- are present during the reaction

Note: Only the solution of the acid in Choice E has :

moles of H+ = mole of OH-

$M_a \times V_a \times$ # of H+ = $M_b \times V_b \times$ # of OH-

(0.5 M) (10 mL) (2) = (1.0 M) (10 mL) (1)

10 moles H+ = 10 moles OH

38. **C** **Raoult's law, partial pressure**

Recall: According to Raoult's law, the vapor pressure of an ideal solution is dependent upon the mole fraction of its components.

Note: For a solution with equal moles of two components:

$VP_{solution}$ = ½ ($VP_{benzene}$) + ½ ($VP_{toluene}$)

Note: According to question, $VP_{benzene}$ is greater than $VP_{toluene}$.

Assume: $VP_{benzene}$ = 100 kPa

$VP_{toluene}$ = 60 kPa

$VP_{solution}$ = ½ ($VP_{benzene}$) + ½ ($VP_{toluene}$)

80 = ½ (100) + ½ (60)

Note: $VP_{solution}$ (80) is less than $VP_{benzene\ (100)}$ BUT greater $VP_{toluene\ (60)}$

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39. E Nuclear decay

Note: During a nuclear decay, the mass number of the product is either smaller (for alpha decays) or stays the same(for beta, positron or gamma decay)

Note: The masses for choices A – D indicates that these isotopes are possible products of iodine – 131 decay.

Note: Cesium – 135 is not a possible decay product of iodine – 131 because its mass is larger than that of iodine – 131.

40. D Hydrogen bonding, Functional group of organic compounds

Recall: Hydrogen bonding is formed between molecules that have a hydrogen atom bonded to an atom of high electronegativity and small radius

Note: Of all the choices listed, only butanoic acid contains a COOH (carboxyl) group in which H is bonded to O (a high electronegativity atom)

41. A Rate law, order of reaction

Recall: The exponent of each substance in the rate law gives the order with respect to that substance.

Rate = k $[BrO_3^-]$ [Br–] [H+]

Note: The exponent of [Br-]in the rate law is 1: The order with respect to Br- is 1

42. A Concentration Change – rate change relationship

Note: Since H+ is a reactant, Increasing [H+] in the reaction will increase the rate proportionally.

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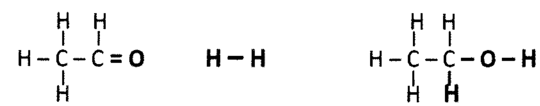
43. C Hess Law, bond energy

Recognize that Hess Law below is essential in solving this problem.

$\Delta H^\circ = \sum \Delta H^\circ \text{Reactants} + \sum \Delta H^\circ \text{products}$

Step 1: Draw out structures of substances in the reaction to help in determining which bonds are broken and which bonds are formed.

$CH_3CHO + H_2$ ----------> CH_3CH_2OH



Step 2: Determine which bonds are broken (on the reactant side) and which bonds are formed (on the product side)

Use Table given to note their energies.

Broken:	C = O	H – H
$H^\circ_{Reactants}$	X KJ/mol	435 KJ/mol

Note: This energies have + values because these bonds are broken (endothermic = +ΔH)

Formed:	C – H	C – O	O – H
$H^\circ_{product}$	- 414 KJ/mol	-351 mol/mol	- 464 KJ/mol

Note: These energies have – values because these bonds are formed (exothermic = **- ΔH°**)

Step 3: *Rewrite* Hess law equation, substitute factors, and solve for X (energy of C = O bond)

$\Delta H^\circ = \sum \Delta H^\circ \text{Reactants} + \sum \Delta H^\circ \text{products}$

$-71 = X + 435 + -1229$

$X = -71 - 435 + 1229 =$ **723 KJ/mol**

44. B **Properties of elements, valance electron, oxidation reaction**

Note: For a molecule to be capable of reacting with oxygen, the + charge of the element (S, N or P) in the formula must be less than the maximum charge the atom can form . This means that the atom CAN BE oxidized further to react with O.

Therefore: The formula that *IS NOT* capable of reacting with oxygen (your answer) must contain S, N, or P with a **a + charge that is equal to the atom's maximum charge value.** This means the atom CANNOT BE be oxidized further.

Note: **maximum + charge value = Number of valance electrons** In another words, an atom cannot lose more valance electrons than it has.

Determine Maximum charge value and Charge in formula

	Formula	*Maximum charge*	*Charge in formula*
(A)	SO_2	S = +6	S = +4
(B)	**SO_3**	**S = +6**	**S = +6**
(C)	NO	N = +5	N = +2
(D)	N_2O	N = +5	N = +1
(E)	P_4O_6	P = +5	P = +3

Note: SO_3 (in Choice B) is the only formula in which the charge of S is equal to the maximum + charge S can form. S *CANNOT BE* oxidized further in this formula.

45. D. **pOH and [H+] relationship**

Recall: 14 = pH + pOH

Determine pH

pH = 14 – pOH

pH = 14 – 4.05 = 9.50

Recall: The value of the exponent of the [H+] must be equal to or close to the value of the pH

Note: in Choice D; 3.2×10^{-10} ⟵ **close to 9.5**

46. E **Solubility – molecular polarity relationship**

Recall: Polarity of a substance determines its solubility in water.

Recall: Polar substances are the most soluble in water. Nonpolar substances are the least soluble in water.

Recognize that Propene (an alkene) is the only nonpolar listed as a choice, and therefore, the least soluble in water.

Note: The rest are either highly polar (Sodium propanoate and Propanoic acid) or slightly polar (Propanediol and Propanone).

47. E **Entropy change of chemical reactions**

Recall: Entropy measures disorder, randomness , or chaos of a system.

Note: According to the question, you are choosing a reaction (system) in which the products have the largest decrease in entropy (or is becoming most organized or most ordered)

Note: Examples of a system with a decreasing entropy are:
Gas ------- > solid or **2** moles of gas -------- > **1** mole of gas

Determine and *compare* changes in order, eliminate choices as you go.

(A) $MgCO_3$**(s)** ------ > MgO(s) + CO_2**(g)**
solid ----------- > gas = more disorder (eliminate A)

(B) **2** NO(g) + **1**O_2(g) --- > **2** NO_2(g)
***3** moles gas ------- > **2** moles gas = more order (keep B)*

(C) $Pb(NO_3)_3$**(aq)** + 2NaCl**(aq)** ---- > $PbCl_2$**(s)** + 2 $NaNO_3$(aq)
aqueous --------------- > solid and aqueous = more order AND the change is greater than B (keep C, eliminate B)

(D) CH_4**(g)** + $2O_2$**(g)** ----- > CO_2(g) + $2H_2O$(l)
gas ---------- > gas and liquid = *more order BUT the change is NOT as great as in C (eliminate D)*

(E) 4 Al(s) + 3 O_2(g) ------ > 2 Al_2O3(s)
gas ---------------- > All solid = More order AND the change is greater than in C ***(keep E,** eliminate C)*

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Questions 48 through 50: Adding half-reactions, reduction potentials

48. **C** *Note:* **Choice A, B, D and E can all be eliminated** because these equations are not balanced as written.

To proof check if **Choice C** is correct, do the followings:

Step 1: Reverse the copper reaction : $Cu \rightarrow Cu^{2+} + 2e^-$

Step 2: Increase moles of electrons to 4: $2Cu \rightarrow 2Cu^{2+} + 4e^-$

Step 3: Write the H_2O reaction: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

Step 3: Add the two equations $\mathbf{2Cu + O_2 + 4H^+ \rightarrow 2Cu^{2+} + 2H_2O}$

49. **B** *Recognize* that the equation below is needed to calculate standard cell potential for the reaction E° for the

$$E^\circ_{cell} = E^\circ_{oxidation} + E^\circ_{reduction}$$

Determine which half-reaction is oxidation and which is reduction. Be sure to reverse the E° sign for oxidation-half.

Note: In a reaction of a metal with nonmetal, the metal (Cu) will always be oxidized, the nonmetal (O_2) will always be reduced.

Oxidation: $Cu \rightarrow Cu^{2+} + 2e^-$ $\quad E^\circ_{oxi} = -0.34\ V$

Reduction: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$ $\quad E^\circ_{red} = +1.23$

Calculate standard cell potential (E°_{cell}) for the reaction

$$E^\circ = E^\circ_{oxidation} + E^\circ_{reduction}$$
$$E^\circ = -0.34\ V + 1.23\ V = \mathbf{+0.89\ V}$$

50. **D** *Recognize* that the equation below is needed to calculate ΔG°

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

Note: n = 4 (moles of electrons involve in the reaction)
F = 96,500 Joules / V^{-1} . mol^{-1} (given)

Substitute factors into equation and solve for ΔG° (free energy change)

$$\Delta G^\circ = -nFE^\circ$$
$$\Delta G^\circ = -4(96{,}500\ J/V^{-1}mol^{-1})(0.89\ V)$$
$$\Delta G^\circ = -343{,}500\ J/mol \approx \mathbf{-340\ KJ/mol}$$

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(see important scoring guideline information on on pg i)

1. **(10 points)**

Benzoic acid acid dissociates in water according to the reaction below.

$C_6H_5COOH\ (aq)\ +\ H_2O(l)\ \text{---->}\ H_3O^+(aq) + C_6H_5COO^-(aq)$

$K_a = 6.17 \times 10^{-5}$

(a) Write the equilibrium constant , K_a, expression for the reaction.

Recall: $K_a = \frac{[\text{Products}]}{[\text{Reactants}]}$

Note: Water has a constant concentration. Therefore, it's never included in equilibrium expressions.

$K_a = \frac{\mathbf{[C_6H_5COO\text{-}][H_3O+]}}{\mathbf{[C_6H_5COO]}}$	**1 point** is earned for the correct expression

(b) Calculate the molar concentration of $C_6H_5COO–$ in a 0.010 *M* benzoic acid solution.

Determine the [ ] of the substances at equilibrium

$[C_6H_5COO\text{-}] = X$

$[H_3O+] = X$

mole ratio of C_6H_5COO- to $[H_3O+]$ in the balanced equation is 1 : 1

$[C_6H_5COO\text{-}] = 0.010\text{ M} - X \approx 0.010\text{M}$ (low dissociation)

1 point is earned for substituting concentration into Ka equation

Substitute factors into K_a expression and solve for X

$K_a = \frac{C_6H_5COO\text{-}][H_3O^+]}{C_6H_5COO]}$

$\mathbf{6.17 \times 10^{-5}} = \frac{\mathbf{(X)\ (X)}}{\mathbf{0.010\ M}}$

$X^2 = 6.17 \times 10^{-7}\text{ M}$

$\mathbf{X = 7.85 \times 10^{-4}\ M = [C_6H_5COO\text{-}]}$

1 point is earned for correctly calculating the $[C_6H_5COO\text{-}]$

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(c) What is the pH of the solution in (b) ?

Note: pH = - log $[H_3O+]$ (see Reference Materials on Pg 339)

Note: $[H_3O+] = [C_6H_5COO\text{-}] = 7.85 \times 10^{-4}$ M

pH = - log $[H_3O+]$ **pH = - log (7.85 x 10^{-4} M)** **pH = 3.1**	**1 point** is earned for setup **1 point** is earned for correct pH

(d) After adding 10.0mL of 5.00×10^{-6} *M* $Ca(OH)_2$ to 90.0mL of an unknown concentration of benzoic acid, the pH of the solution is 5.26. Calculate each of the followings:

(i) The [H+] of the solution after the addition of $Ca(OH)_2$.

Recall: $[H+] = 10^{-pH}$

$[H+] = 10^{-pH}$ $\mathbf{[H+]} = 10^{-5.26} = \mathbf{5.5 \times 10^{-6}\ M}$	**1 point** is earned for the correct pH

(ii) The [OH–] of the solution after the addition of $Ca(OH)_2$.

Recall: $[H+] \times [OH\text{-}] = 1.0 \times 10^{-14}$

$\mathbf{[OH\text{-}]} = \frac{1.0 \times 10^{-14}}{[H+]} = \frac{\mathbf{1.0 \times 10^{-14}}}{\mathbf{5.5 \times 10^{-6}\ M}}$ $\mathbf{[OH\text{-}] = 1.82 \times 10^{-9}\ M.}$	**1 point** is earned for setup **1 point** is earned for correct [OH-]

(iii) Write a balanced equation for the reaction of the benzoic acid and calcium hydroxide.

Note: This a double replacement (ion-exchange) neutralization reaction.

Recall: Water and salt are produced in neutralization reactions.

$\mathbf{2\ C_6H_5COOH\ +\ Ca(OH)\ \text{---->}\ H_2O\ +\ Ca(C_6H_5COO)_2}$ *acid* *base* *water* *salt*	**1 point** is earned for correct equation

(e) State whether the solution at the equivalence point of this titration is acidic, basic, or neutral. Explain your reasoning.

The solution at equivalent point will be basic because **calcium benzoate, a basic salt, is formed during the titration.**	**1 point** is earned for stating solution is basic with correct explanation

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2. **(10 points)**

A student uses spectrophotometer to collect data on the first order decomposition of a colored chemical species, Z, into colorless products.

The molar absorptivity of Z is 5.0×10^3 /(cm.M). The cuvette containing the reaction mixture has a path length of 1.0 cm.

The data table contains information collected by the student.

(a) What is the initial concentration of the colored species?

Recall: Concentration (c) is related to Absorbance (A), molar absorptivity (a), and path length of cuvette (b) by the equation:

$A = abc$

$c = \frac{A}{ab}$ $c = \frac{1.20}{(5.0 \times 10^3\ cm^{-1} M^{-1})(1.00\ cm)}$ $\mathbf{c = 2.4 \times 10^{-4}\ M}$	**1 point** for the correct concentration

(b) Based on the information provided on the table, determine the rate constant for the first order reaction. Include all units with your answer.

Note:

$$\ln \frac{[Z]\,t_1}{[Z]\,t_0} = -kt$$ (see Reference Materials on Pg)

$\ln \frac{[8.0 \times 10^{-5}]}{[2.4 \times 10^{-4}]} = -k\,(25\ min)$	**1 point** for setup
$\ln (.333) = -k\,(25\ min)$ $-1.10 = -k\,(25\ min)$ $\mathbf{4.4 \times 10^{-2}\ min^{-1} = k}$	**1 point** for calculating the rate constant with the correct unit.

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(c) How much time had elapsed from when the absorbance goes from 1.20 to 0.150.

Note: Use the same setup and equation as in question (b), except now k is known, and you are solving for t .
Be sure to substitute [Z] that corresponds to the absorbance values mentioned in the question.

$\ln \frac{[Z]\, t_4}{[Z]\, t_o} = -kt$	
$\ln \frac{[3.0 \times 10^{-5}]}{[2.4 \times 10^{-4}]} = -(4.4 \times 10^{-2})\,(t)$	**1 point** for setup
$\ln (.125) = -(4.4 \times 10^{-2})\,(t)$	
$-2.08 = -(4.4 \times 10^{-2})\,(t)$	
47.2 min = t	**1 point** for calculating correct time

(d) Determine the half-life of the reaction performed by the student.

Note: Since this is a first order reaction, half-life ($t_{1/2}$) can be calculated with the equation:

$t_{1/2} = \frac{\ln(^1/_2)}{k}$ (see reference material pg

$t_{1/2} = \frac{0.693}{4.4 \times 10^{-2}}$	**1 point** for setup
$t_{1/2} =$ **15.75 min**	**1 point** for the correct half-life

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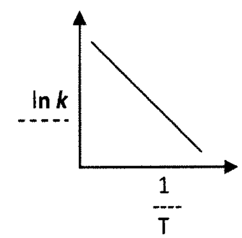
(e) The student performed more experiments to determine the rate constant at various temperature, T. The student plotted the graph below from data she collected from the experiments.

(i) Label the vertical axis of the graph.



1 point for labeling axis **ln *k***

(ii) Explain how the student can calculate the activation energy, E_a, for the reaction using information provided by the graph.

Recall: slope $= -\frac{E_a}{R}$ where R is the gas constant.

The student should **determine slope of the line.**	**1 point** for mentioning slope must be determined
The student would then **multiply the slope by the gas constant (R)** to get the activation energy (E_a) for the reaction.	**1 point** for explanation that include slope and R

Day 18 Question 2: Space for Work and Answers

Day 18: Answers and Scoring Guidelines

(see important scoring guideline information on on pg i)

(a) A solution of ammonium thiocyanate is added to a solution of iron (III) nitrate.

Note: This reaction involve the formation of a complex ion
Ammonium and nitrate ions are spectator ions

(i) Balanced equation **Fe^{3+} + SCN- ------> $Fe(SCN)^{2+}$** *complex ion*	**1 point** is earned for correct reactants **2 points are** earned for correct products **1 point** is earned for correctly balancing the equation

(ii) What is mass of 0. 12 mole of ammonium thiocynate?

Recall: Mass = moles x molar mass of NH_4SCN

Mass = 0.12 mol x 76 g/mol = **9.1 g**	**1 point** is earned for the correct grams

(b) Carbon dioxide gas is bubbled through a concentrated solution of sodium hydroxide.

Note: This is a neutralization reaction involving a nonmetal oxide
The sodium anion (Na+) is the spectator ion, therefore, not included in the equation

(i) Balanced equation **CO_2 + 2OH- -------> CO_3^{2-} + H_2O** *nonmetal oxide* — *base* — *salt* — *water*	**1 point** is earned for correct reactants **2 points are** earned for correct products **1 point** is earned for correctly balancing the equation

(ii) What happens to the pH of the sodium hydroxide as carbon dioxide is added to it.

The pH of the sodium hydroxide will decrease because carbon dioxide is weakly acidic, and will slowly neutralize the base.	**1 point** is earned for stating pH will decrease

(c) Calcium chloride dihydrate is gently heated in an open test tube.

Recall: Hydrates are ionic substances with attached water molecules. When heated, a hydrate decomposed into the ionic salt and water (which will evaporate out of the test tube)

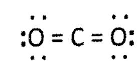
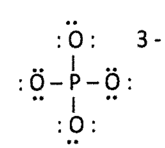
(i) Balanced equation **$CaCl_2 . 2H_2O$ ----------> $CaCl_2$ + $2H_2O$**	**1 point** is earned for correct reactants **2 points are** earned for correct products **1 point** is earned for correctly balancing the equation

(ii) If 10 grams of calcium chloride dihydrate is heated for 5 minutes, would the mass of the content of the test tube after heating be greater than 10 gram, equal to 10 grams, or less than 10 grams. Explain.

Less than 10 because **the water that evaporated out of the open test tube will account for the missing mass**	**1 point** is earned for stating less than 10 g with correct explanation.

2) 2. Answer each of the following questions about CO_2 and PO_4^{3-} ion
(8 point)

(a) Draw a complete Lewis electron-dot diagram for CO_2 and for PO_4^{3-}

 carbon dioxide	**1 point** for correct diagram for CO_2
 phosphate ion	**1 point** for correct diagram for PO_4^{3-}

(b) On the basis of your Lewis diagram from part (a), identify the hybridization of the central carbon atom in CO_2 and the central phosphorous atom in PO_4^{3-}.

In **CO_2**, the **C** atom forms **sp hybrization** *Note:* When drawn correctly, CO_2 has a linear shape, hence, the **sp** hybridization.	**1 point** for stating sp for C
In **PO_4^{3-}**, the **P** atom forms **sp^3** hybridization *Note:* When drawn correctly, PO_4^{3-} has a tetrahedral shape, hence, the **sp^3** hybrization.	**1 point** for stating sp^3 for P

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(c) When carbon dioxide dissolves in water, a small fraction (at equilibrium) of the carbon dioxide reacts with water to form carbonic acid. Write out a complete, balanced equation for this reaction and identify the Lewis acid and the Lewis base in the reaction.

Recall: Lewis base donates electrons in reactions

Lewis acids accept electrons in reactions

CO_2 + H_2O --------> H_2CO_3. **Lewis base: H_2O** The **O** donates a pair of electrons to CO_2	**1 point** for correct Lewis base
Lewis acid: CO_2 The **C** accepts the pair of electrons from O	**1 point** for correct Lewis acid

(d) Is CO_2 polar? Explain.

CO_2 is not polar. The two C = O bonds are polar because of the electronegativity difference between the two nonmetals. However, CO_2 is nonpolar because **the + charges (on C atom) and the – charges (on the O atoms) are evenly and symmetrically distributed.** or **Dipole moments cancel out.**	**1 point** for not polar with correct justification

(e) What is the O-P-O bond angle in PO_4^{3-}?

The bond angle is 109.5 degrees. bond angle is common for sp^3 hybridized (tetrahedral shape) molecules.	**1 point** for correct bond angle