Day 1: Answers and Explanations

Answers: Quick Check

1. **D**	2. **B**	3. **E**	4. **B**	5. **D**	6. **E**	7. **C**	8. **C**	9. **C**	10. **A**
11. **C**	12. **D**	13. **E**	14. **E**	15. **E**	16. **A**	17. **A**	18. **B**	19. **D**	20. **A**
21. **D**	22. **D**	23. **C**	24. **C**	25. **E**					

Answers and explanations — Major concepts tested by the question.

1. **D** **Molecular size-rate of diffusion relationship, Graham's Law**
Recall: Greatest mass molecules diffuse at the slowest rate.
Determine: NO_2 has the greatest molar mass (46g/mol) of those listed.

2. **B** **Molecular polarity-molecular attraction relationship**
Recall: Nonpolar molecules have the weakest interacting molecules.
Determine: O_2 (nonpolar bond and symmetrical) is the only nonpolar molecule listed.

3. **E** **Molecular size-rate of diffusion relationship, Graham's Law**
Recall: Kinetic energy = ½ (mass) $(velocity)^2$
Interpret: Velocity is relative to the mass of the moving molecules. Smallest Mass molecules have the greatest velocity.
Determine: CO has the smallest molar mass (24 g/mol) of those listed.

Questions 4 through 7: hybridization, molecular geometry, electron pairs

Step 1: Determine number of electron pairs around the central atom in the given molecules

Step 2: Determine or recall electron geometry associated with the number of electron pairs you determined in step 1

Step 3: Determine or recall hybridization associated with the number of electron pair or geometry you determine

	Molecule	*electron pairs*	*electron geometry*	*hybridization*
4. **B**	SO_2	3	trigonal planer	sp^2
5. **D**	I_3^-	5	trigonal bipyramidal	sp^3d
6. **E**	IF_5	6	octahedral	sp^3d^2
7. **C**	CH_3OH	4	tetrahedral	sp^3

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8. **C** **Mole concept, mass calculation**

Determine grams of Zn by utilizing mole ratio from the balanced equation in factor labeling.

1 Zn(s) ------ > **2** Ag(s)

$$1.0 \text{ mol Ag} \times \frac{\textbf{1} \text{ mol Zn}}{\textbf{2} \text{ mol Ag}} \times \frac{65.4 \text{ g Zn}}{1 \text{ mol Zn}} = \textbf{33 g Zn}$$

9. **C** **Thermodynamic, enthalpy, energy calculation**

Step 1: Determine factors from questions

$\Delta E = ?$ $\Delta H = 505.64 \text{ J}$
$P = 2 \text{ atm}$ $\Delta V = 6\text{L} - 5\text{ L} = 1\text{ L}$

Step 2: *Determine* or recall equation associated with factors given

$\Delta E = \Delta H - (P \times \Delta V)$

Step 3: Substitute factors into equation and solve

$\Delta E = \Delta H - (P \times \Delta V)$

$$\Delta E = 505.64 \text{ J} - (2 \text{ atm} \times 1 \text{ L}) \times \frac{101.3 \text{ J}}{(\text{L} \times \text{atm})} = \textbf{303.00 J}$$

10. **A** **Raoult's Law, partial pressure, mole fraction**

Recall Raoult's Law Equation:

$P_A = P_A^{\circ} X_A$ P_A = Vapor pressure of solvent A in solution
P_A^0 = Vapor pressure of pure solvent A
X_A = mole fraction of solvent A in solution

Note: When information given in each choice is considered in terms of the Raoult's law, Choice A is false. Opposite will be true.

11. **C** **Lewis structure, molecular structure, lone pair electrons**

Draw Lewis structure for HCl

There are 3 lone pairs (nonbonding pair) of electrons

12. **D** **Equilibrium, Le Chatelier's principle**

$MgO(s) + H_2(g)$ ----> $Mg(s) + H_2O(g)$ $\Delta H = -14.0$ kilojoules

Note: Reaction is exothermic b/c ΔH is negative.

Recall: A decrease in heat temperature (Choice D) forces the reaction in the exothermic direction (favors products)

Note: ↑[MgO], ↑[H_2], ↓[Mg] and ↓[H_2O] will also favor products. But none of these is given as a choice.

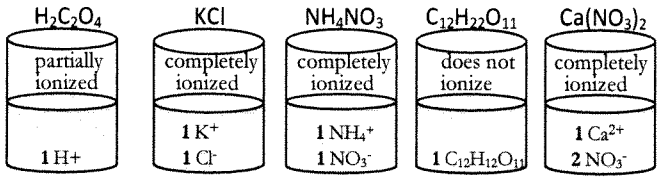
13. **E** **Colligative property, boiling point elevation, Van't Hoff factor.**

Recall equation: $\Delta T = k_b \times m \times i$

Note: All three solutions have that same m (molality) and kb (boiling point elevation constant)

Therefore, solution with the greatest i (Van't Hoff factor, number of dissolved particles) value will have the greatest change in temperature (ΔT) and also the highest boiling point.

Determine: **$Ca(NO_3)_2$**, (an ionic compound) produces the most (3) dissolved particles:



14. **E** **Mole concept, mole interpretation**

Not: The true statement to this problem is best determined by calculating and comparing number of moles (number of molecules) of O_2 and He

Recall equation: $\text{mole} = \dfrac{\text{mass given}}{\text{molar mass}}$

Calculate moles of O_2 and He:

$$\text{moles of } O_2 = \frac{100\text{ g}}{32\text{ g. mole}^{-1}} \qquad \text{moles of He} = \frac{100\text{ g}}{4\text{ g.mole}^{-1}}$$

moles of O_2 = 3.1 mole O_2 moles of He = 25 mole He

Relate: Choice E is the only true statement since there is greater moles (more molecules) of He than O_2.

15. **E** **Isoelectronic, ions, determining number of electrons**

Recall: Isoelectronic refers to particles with the same number of electrons

Determine and compare number of electrons in each particle.

S^{2-} (18 e-) Cl^- (18 e-) Ar (18 e-) K^+ (18 e-) **Mg^{2+} (10 e-)**

Note: All, except Mg^{2+}, have the same number of electrons

16. **A** **Acid dissociation constant, K_a, calculation**

Step 1: Assume that HX is the monoprotic acid, write the dissociation equation

HX -----> H+ + X-

Step 2: Write K_a expression based on equation in step 1

$$K_a = \frac{[H+]\,[X-]}{[HX]}$$

Step 3: Determine concentrations to put into equation:

$[H+] = 1.0 \times 10^{-5}$ M because pH = 5

$[X-] = 1.0 \times 10^{-5}$ M because for monoprotic acids, [H+] = [X-]

[HX] = 1 M because weak acids dissociate very little. Therefore [HX] stays relatively unchanged.

Step 4: Substitute factors into Ka equation and solve

$$K_a = \frac{(1 \times 10^{-5}\text{ M})(1 \times 10^{-5}\text{ M})}{1\text{ M}} = \mathbf{1 \times 10^{-10}}$$

17. **A** **Half-life, nuclear decay**

Step 1: Determine number of half-life periods (n) from length of time (t) and half-life (T)

$$n = \frac{t}{T} = \frac{34480}{5730} \approx 6$$

Step 2: Determine fraction remaining using equation

$$\text{Fraction remaining} = \frac{1}{2^n} = \frac{1}{2 \times 2 \times 2 \times 2 \times 2 \times 2} = \frac{1}{64}$$

Step 3: Change fraction to percent

$$\frac{1}{64} \times 100 = \mathbf{1.56\ \%}$$

18. **B** **Periodic Trend**

Note: Magnesium (Mg) and calcium (Ca) are in the same Group

Recall these Periodic Table trends **from Top to Bottom** of a Group:
Ionization Energy decreases
Atomic Radius increases

Relate: Mg (higher up on the Table than Ca) will have a larger ionization energy BUT a smaller atomic radius

19. **D** **Ions, Oxidation number**

Note: The correct formula of each ion must be known in order to correctly determine the charge of Cr in each ion

Recall: The sum of all charges (+ and -) in each formula must equal the overall charge of the ion (**-2**)

Step 1: Write the correct formulas for both ions

chromate: CrO_4^{2-}

dichromate: $Cr_2O_7^{2-}$

Step 2: Calculate total – charge from O in each formula
Recall: Oxygen has a charge of -2 in most formulas

Total negative in CrO_4^{2-} = -8 (4 x -2)

Total negative in $Cr_2O_7^{2-}$ = -14 (7 x -2)

Step 3: Determine charge of Cr needed so that sum of all charges in each formula = **-2**

CrO_4^{2-} Cr = +6 check: (+6 + -8 = -2)

$Cr_2O_7^{2-}$ Cr = +6 check: (2(+6) + -14 = -2)

20. **A** **Entropy Change in reactions**

Note: ΔS is entropy (disorder) change of a system

Recall: +ΔS means that a system entropy is increasing (it is becoming more disorder)

Example of a +ΔS change : solid ---------- > gas

Note: Of the reactions listed, only Choice A reaction

$MgCO_3(s)$ --------> $Mg(s) + CO_2(g)$

is changing from a solid reactant to a gaseous product

Day 1: Answers and Explanations

21. **D** **Henry's law, Partial Pressure, Calculation**

Recognize that, based on information given in question, concentration (C) of N_2 can be calculated using Henry's law equation:

$C = kP$ where k is constant

Step 1: Determine k from initial pressure (P_i)and concentration $[N_2]_i$

$$k = \frac{[N_2]_i}{P_i} = \frac{6.0 \times 10^{-4}\ M}{1\ atm} = 6.0 \times 10^{-4}\ M.\ atm^{-1}$$

Step 2: Calculate Partial pressure (P) of N_2 based on mole % and total pressure

$P = 0.80 \times 3.0\ atm = 2.4\ atm$

Step 3: Substitute factors into Henry's law and solve for C

$C = kP = (6.0 \times 10^{-4}\ M.\ atm^{-1})(2.4\ atm) =$ **1.4×10^{-3} M**

22. **D** **Rate, Order of reaction**

Step 1: Assume that X represents the change to [B] you are asked to determine.

Step 2: Write rate quotient based on the rate law given and the fact that the new rate ($Rate_f$) is proceeding at 50% ($^1/_2$) that of the initial rate ($Rate_i$) .

$$\frac{Rate_f}{Rate_i} = \frac{1}{2} = \frac{k[A/2]^2 \cdot X[B]}{k[A]^2 \cdot [B]} = \frac{X}{4}$$

Step 3: Solve for X: When all factors are crossed-out

X = 2 (double)

Day 1: Answers and Explanations

23. **C** **Titration curve**

Recall: A weak base will a pH less than 12 but greater than 7.

A strong acid have pH of 2 or less.

Note: Choice C curve shows:

The starting pH is slightly lower than 12. This reflects the pH of the weak base.

The ending pH is lower than 2. This reflect the fact that at the end of the titration, all of the base have been neutralized, and the solution is of a strong acid.

24. **C** **Electron configuration, quantum numbers**

Recall: Symbol of an oxide ion is O^{2-}

Determine number of electrons in O^{2-} = 10 e-

Determine correct electron configuration for 10e- **($1s^2 2s^2 2p^6$)**

25. **E** **Phase change diagram**

Recall that the normal boiling point of a substance is the point (or temperature) at which liquid and vapor coexist at equilibrium at normal (standard) atmospheric pressure (1 atm).

Note: line AB of the graph is the transition line from liquid to vapor (boiling). For normal boiling point to be determined from the graph, AB must cross the 1 atm dash line. This is NOT the case, therefore, normal boiling point can't be determined.

Day 2: Answers and Scoring Guidelines

(see important scoring guideline information on page i)

1. **(10 points)**

Formic acid is a significant component of bee venom. Also known as methanoic acid, formic acid has an acid dissociation constant, K_a, of 1.80×10^{-4}.

a) If a bottle contains 0.25*M* solution of formic acid.

(i) Write the equilibrium expression for the dissociation of the acid.

Recall: $K_a = \dfrac{[\text{products}]}{[\text{reactants}]}$

Write dissociation equation HCOOH <===> H+ + HCOO- *Write equilibrium expression from your equation* $K_a = \dfrac{[\text{products}]}{[\text{reactants}]} = \dfrac{[H^+][HCOO^-]}{[HCOOH]}$	**1 point** is earned for writing the correct equilibrium expression

(ii) Calculate the pOH of the solution.

Recall: pOH = 14 – pH or pOH = -log[OH-]

Note: pH or [OH-] must be determine from known information

Determine concentrations at equilibrium

[HCOOH] = 0.25M - X ≈ 0.25 M (weak acid dissociates very little)

[H+] = X

[HCOO-] = [H+] = X (1 : 1 mole ratio in equation)

Substitute [ ] into K_a expression and solve for X

$$K_a = \frac{[H+][HCOO-]}{[HCOOH]}$$

$$1.80 \times 10^{-4} = \frac{(X)(X)}{0.25} = \frac{X^2}{0.25}$$

$$X^2 = 4.5 \times 10^{-5}$$

$X = 6.7 \times 10^{-3}$ M = [H+]

1 point is earned for calculating [H+] or [OH-]

Determine [OH-]

$$\textbf{[OH-]} = \frac{kw}{[H+]} = \frac{1.0 \times 10^{-14}}{6.7 \times 10^{-3}} = \textbf{1.49 x } \mathbf{10^{-12}}\textbf{ M}$$

Determine pOH from pH

pH = -log [H+] = -log (6.7 x 10^{-3}) = 2.17

pOH = 14 - pH = 14 - 2.17 = **11.83**

or

Determine pOH from [OH-]

pOH = -log [OH-] = -log (1.49 x 10^{-12}) = **11.83**

1 point is earned for correctly calculating the pOH (11.83)

Day 2: Answers and Scoring Guidelines

(b) Calculate the percent dissociation of the solution in part (a).

Note: [HCOO-] = [H+] = 6.7 x 10^{-3} M

$$\% \text{ dissociation} = \frac{[HCOO-]}{[HCOOH] + [HCOO-]} \times 100$$

$$\% \text{ dissociation} = \frac{\mathbf{6.7 \times 10^{-3}}}{\mathbf{0.25 + (6.7 \times 10^{-3})}} \times \mathbf{100}$$

1 point is earned for setup

% dissociation = **2.6%**

1 point is earned for correctly calculating the percent dissociation.

(c) Calculate the pH of a solution prepared by mixing equal 1.00L volumes of 0.25*M* formic acid and 0.20*M* sodium methanoate.

Note: This is a buffer problem in which the pH can be calculated using Henderson-Hasselbalch equation.

$$pH = pka + \log \frac{[HCOO-]}{[HCOOH]}$$

$$pH = -\log (1.8 \times 10^{-4}) + \log \frac{.20}{.25}$$

pH = 3.74 + (-0.096) = **3.64**

1 point is earned for correctly calculating the pH

d) Using only compounds already mentioned, what should be added to the solution in part (c) to produce a solution with maximum capacity to resist change in pH?

(i) Mention the compound to be added.

Sodium formate (NaHCOO) should be added

1 point earned for mentioning sodium formate

(ii) Calculate the mass of the compound to be added.

Before solving: *Note* the following important information .

Maximum buffering occurs when the solution contains equal concentration of the conjugate acid (HCOOH, formic) and conjugate base (HCOO-, formate ion).

The total volume of the solution is 2 L

Note: Moles of formate to be added must be calculated before mass can be determined.

Determine initial [formic acid] and [formate ion] **[formic]** = $\frac{.25 \text{ mole}}{2 \text{ L}}$ = **0.13 mol/L formic acid** **[formate]** = $\frac{.20 \text{ mol}}{2 \text{ L}}$ = **0.10 mol/ L formate** *Note* that more formate must be added to bring its [ ] to 0.13 mol/L (equal to that of the conjugate acid as *noted* above)	**1 point** is earned for calculating initial concentrations of formic and formate.
Determine moles of formate (X) to be added: $\frac{(0.10 \text{ mol} + X \text{ mol})}{2 \text{ L}} = \frac{0.13 \text{ mol}}{\text{L}}$ **X = 0.16 mol of formate** must be added in the form of sodium formate (MW: 68 g/mol)	**1 point** is earned for calculating moles of formate to be added
Calculate mass of 0.16 moles of sodium formate: Mass = moles x molar mass **Mass** = 0.16 mol x 68 g/mol = **11 g**	**1 point** is earned for correctly calculating mass of sodium formate to be added.

Day 2: Answers and Scoring Guidelines

2. **(10 points)**

Refer to the following equation.

2 Mg(s) + **2** $CuSO_4$(aq) + H_2O(l) ----> **2** $MgSO_4$(aq) + Cu_2O + H_2(g)

(a) If 1.46 grams of Mg(s) are added to 500 mL of a 0.200 M solution of $CuSO_4$, what is the maximum molar yield of H_2(g)

Note: Molar yield of H_2 depends on the number of moles of the limiting reagent in the reaction.

Determine the limiting reagent **Moles of Mg** = $\frac{\text{mass of Mg}}{\text{MW Mg}} = \frac{1.46 \text{ g}}{24 \text{ g/mol}}$ = **0.060 mol Mg** Moles of $CuSO_4$ = Molarity x volume **Moles of $CuSO_4$** = (0.200 moles/L) x (0.500 L) = **0.100 mol**	**1 point** is earned for calculating moles of Mg and $CuSO_4$
Note: Water is always in excess *Therefore:* **Limiting reagent is Mg(s)** since its moles is the smaller of the two.	**1 point** is earned for correctly identifying the limiting reagent.
Determine molar yield of H_2 using mole ratio of Mg to H_2 in the equation. 0.060 mol Mg x $\frac{1 \text{ mol } H_2}{2 \text{ mol Mg}}$ = **0.030 moles H_2**	**1 point** is earned for correctly calculating molar yield of H_2

(b) When all the limiting reagent has been consumed in (a), how many grams of the other reactant (not water) remain?

Note: The other reactant is $CuSO_4$

Determine moles of $CuSO_4$ that reacted with Mg $0.060 \text{ mol Mg} \times \frac{2 \text{ mol } CuSO_4}{2 \text{ mol Mg}} = \mathbf{0.060 \text{ mol } CuSO_4}$	**1 point** is earned calculating moles of $CuSO_4$ that reacted
Determine moles of $CuSO_4$ that remained Moles remaining = moles at start (a) - moles reacted (b) moles remaining = 0.100 mol - 0.060 mol Moles remaining = **0.040 moles $CuSO_4$**	**1 point** is earned for correctly calculating moles of $CuSO_4$ that remained
Determine mass of $CuSO_4$ that remained Mass = moles x molar Weight **Mass** = 0.040 mol x 160 g/mol = **6.4 g $CuSO_4$**	**1 point** is earned for correctly calculating the mass of $CuSO_4$ that remained

(c) What is the mass of the Cu_2O produced in (a)

Determine moles of Cu_2O using mole ratio in equation $0.060 \text{ mol Mg} \times \frac{1 \text{ mol } Cu_2O}{2 \text{ mol Mg}} = \mathbf{0.030 \text{ mol } Cu_2O}$	**1 point** is earned for calculating moles of Cu_2O
Calculate mass of Cu_2O from moles Mass = moles x Molar weight **Mass** = 0.030 mol x 143 g/mol = **4.29 g**	**1 point** is earned for correctly calculating the mass of Cu_2O

Day 2: Answers and Scoring Guidelines

(d) What is the concentration of Mg^{2+} in the solution at the end of the experiment? Assume that the volume of the solution remains unchanged.

Note: Moles of Mg(s) = moles of Mg^{2+} = 0.060 mol	
$[Mg^{2+}] = \frac{\text{moles } Mg^{2+}}{\text{L of solution}}$	
$[Mg^{2+}] = \frac{\mathbf{0.060 \text{ mol}}}{\mathbf{0.500 \text{ L}}}$	**1 point** is earned for correct setup
$[Mg^{2+}]$ = 0.120 M	**1 point** is earned for $[Mg^{2+}]$ that corresponds to your setup

Day 3: Answers and Scoring Guidelines

(see important scoring guideline information on on pg i)

1. **15 points**

(a) A piece of solid tin is heated in the presence of chlorine gas.

Note: This is a combination reaction

(i) Balanced equation $Sn + 2Cl_2 \text{ ------ > } SnCl_4$	**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 the oxidation number of the tin before and after the reaction.

Recall: Charge of a free element is 0.
Sum of charges in a neutral formula must equal zero

0 before reaction *(tin is free element)* **+4** after reaction *(allows total charge in $SnCl_4$ to equal 0)*	**1 point** is earned for correct charges before and after the reaction

(b) Ethane is burned completely in air.

Recall: Burning (combustion) requires oxygen.
Carbon dioxide and water are produced from combustion.

(i) Balanced equation $2C_2H_6 + 7O_2 \text{ ------- > } 4CO_2 + 6H_2O$	**1 point** is earned for correct reactants **2 point** are earned for correct products **1 point** is earned for correctly balancing the equation

Day 3: Answers and Scoring Guidelines

(ii) How many liters of carbon dioxide will be produced from completely burning 3.4 moles of ethane at STP?

$\text{Volume} = 3.4 \text{ mol } C_2H_6 \times \frac{4 \text{ mol } CO_2}{2 \text{ mol } C_2H_6} \times \frac{22.4 \text{ L } CO_2}{1 \text{ mol } CO_2}$ **Volume = 152.3 L CO_2**	**1 point** is earned for correctly calculating the liters of CO_2

(c) A pellet of zinc is dropped into a test containing 30 mL of 6M HCl.

Note: This is a single replacement (or redox) reaction.
The chlorine is unchanged (oxidation number stays the same) in the reaction. Cl should not be included in the equation.

(i) Balanced equation: $Zn + 2H^+ \text{ ------- > } H_2 + Zn^{2+}$	**1 point** is earned for correct reactants **2 points** are earned for correct products **1 point** is earned for correctly balancing the equation

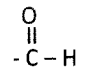
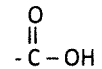
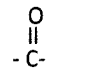
(ii) Indicate two observable changes that will be noted as the reaction proceeds in the test tube.

The liquid mixture will bubble. **Gas escaping from the test tube.** **The test will feel much hotter than before the reaction .**	**1 point is** earned for correctly listing two observations that are typical for this reaction.

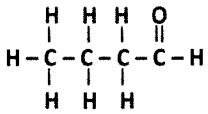
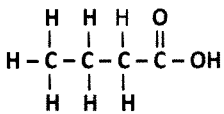
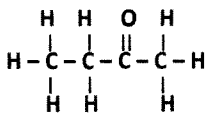
Day 3: Answers and Scoring Guidelines

2. A set of three vials contains three different organic compounds. Each compound contains only one kind of functional group, and each functional group is different from the others. None of the compounds has an ester or amide functional group, and none is an alkene or alkyne. **8 points**

(a) All of the compounds possess a carbonyl group. What kinds of compounds are these three?

Aldehyde  **Organic acid**  **Ketone** 	**1 point** is earned for each correctly identified each compound (**3 points** total)

(b) Assuming that each of the three compounds contains four carbon atoms, and is linear (not branched), draw Lewis structures for the three compounds.

 butanal  butanoic acid  butanone	**1 point** is earned for correctly drawing the Lewis structure for each compound (**3 points** total)

Day 3: Answers and Scoring Guidelines

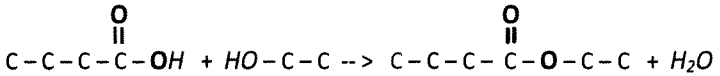
(c) Ethanol is added to each of the three vials. With which of the three compounds is ethanol most likely to react to produce an ester?

Recall: An ester can be synthesize through condensation polymerization reactions between an organic acid and alcohol

Organic acid	**1 point** is earned for correctly identifying organic acid

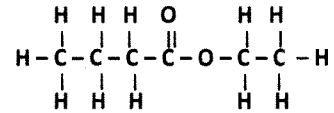
(d) Draw the Lewis structure and name the ester that would be produced in the reaction described in part (c).

Note: The complete equation to the reaction described in (c)



organic acid *alcohol* *ester* *water*

(butanoic) *(ethanol)* *(ethyl butanoate)*

 **ethyl butanoate**	**1 point** is earned for correctly drawing and naming the ester that is produced.

Day 4: Continue

23. Pi bonding occurs in each of the following species except

(A) N_2F_2
(B) C_2H_2
(C) HCN
(D) C_6H_6
(E) CCl_4

24. You can prepare 0.75 molal NaCl by dissolving 15 g NaCl in what amount of water?

(A) 0.40kg
(B) 0.34kg
(C) 0.27kg
(D) 0.20kg
(E) 0.26kg

25. The formulas CH_3CH_2COOH and CH_3COCH_2OH would be expected to have the same values for which of the following? (Assume ideal behavior.)

(A) Freezing points
(B) Boiling points
(C) Specific heat capacity
(D) Percent composition
(E) Heats of combustion

Day 4

STOP. Correct your answers and note how many correct **points**

Day 4: Answers and Explanations

Answers: Quick Check

1. **A**	2. **B**	3. **A**	4. **D**	5. **A**	6. **A**	7. **C**	8. **B**	9. **D**	10. **A**
11. **A**	12. **C**	13. **E**	14. **D**	15. **D**	16. **A**	17. **C**	18. **B**	19. **E**	20. **C**
21. **B**	22. **C**	23. **E**	24. **B**	25. **D**					

Answers and Explanations

Question 1 through 4: Properties of metals, atomic structure

1. **A** *Note:* The list includes all metals. However, only K will react vigorously in cold water because K, an alkali (Group 1) metal, is the most reactive of all the metals listed.

   $K + H_2O$ -----> $H_2 + KOH +$ heat

2. **B** *Note:* Mn, Cr, Zn and Ag are all transitional metals

   Recall: Transition metals tend to form multiple oxidation numbers. Common oxidation states of the four metals are listed below.
   Mn: +2 +3 +4 +7 Cr: +3 +4 +6 Zn: +2 Ag: +1

   Note: Mn has the most oxidation states. You do need to memorize oxidation states of some common elements.

3. **A** *Recall:* Electronegativity values (a measure of atom's attraction to electrons) are lowest for elements to the left of the Periodic Table.

   K (farthest left) will have the lowest electronegative value of those listed. In general, alkali metals tends to have the the lowest electronegativity values.

4. **D** *Note:* An element with no unpaired electrons will have an even number of electrons in all of its sublevels.

   Recognize that of all elements listed, the electron configuration of Zn: [Ar] $4s^2\ 3d^{10}$, is the only one with even number of electrons in all of its sublevels.

Day 4: Answers and Explanations

Questions 5 through 8: Entropy changes in reactions

5. **A** *Note:* In this system, the number of particles is increasing from **1** F_2 molecule -----> **2 F** atoms

Recall: Increase in number of particles indicates an increase in entropy (+ΔS) Choice A.

6. **A** *Note:* In this system, pressure is decreasing from 5 atm to 1 atm. Therefore, more space for the He particles to move more freely (show more chaos).

Relate: Decrease in pressure means increase in entropy (+ΔS)

7. **C** *Note:* In this system, the number of particles is decreasing from **3** particles (**2** H_2 + **1** O_2) on the left to 2 particles (**2** H_2O) on the right.

Recall: Decrease in number of particles indicates a decrease in entropy (-ΔS) Choice C.

8. **B** *Note:* In this system, the reaction is at equilibrium (rate of forward and rate of reverse are equal)

Therefore, no one side is becoming more or less disorder than the other (No change in entropy)

Recall: Zero entropy means no change in disorder. (Choice B)

9. **D** **Solubility rules, soluble and insoluble compounds**

Recall: The solubility rules for the ions in compounds.

Note: **$Zn(OH)_2$** contains hydroxide ion (**OH-**) which forms mostly **insoluble compounds,** except when it combines with a Group 1 ion or an ammonium ion (NH_4^+)

Note: All other choices contain soluble ions (Cl-, NO_3^- and Na)

10. **A** **Enthalpy and Entropy change in a physical change**

Recall: When a solid melts, it changes from solid ----> liquid

Relate: Melting releases heat, exothermic (-ΔH or H < 0)

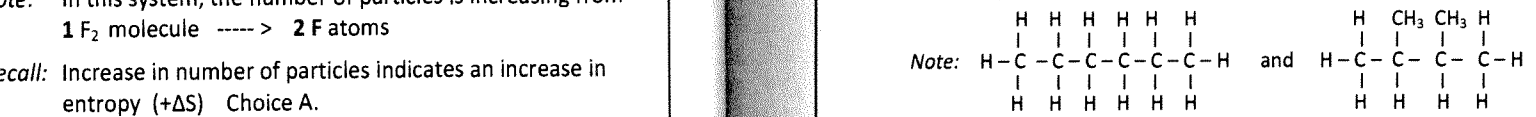
Relate: Melting results in increase in entropy (+ΔS or ΔS > 0)

Day 4: Answers and Explanations

11. **A** **Isomers, hydrocarbons, IUPAC names**

Recall: Isomers are compounds with same percent composition (same molecular formula)

Note:



n-hexane and 2,3-dimethybutane have the same molecular formula (C_6H_{14})

12. **C** **Equilibrium constant, base strength, base reactions**

Recall the equilibrium constant (*k*) equation:

$$k = \frac{[\text{product}]}{[\text{reactant}]}$$

Note: For *k* to be less than 1 (as stated in question), [reactant] must be greater than [product].

Recognize that based on the list of base strength and information in question, the correct equation must have the stronger base on the reactant (left) side.

Note: Of all the equation listed, only in Choice **e**quation is the stronger base (LiOH) appearing on the reactant side.

13. **E** **Phase diagram, critical point**

Recall: Critical point of a phase diagram is the point at which no amount of pressure can cause a substance in the gas state to change back to a liquid.

Note: The critical point (Point E) of phase diagram is always located farthest right of all the points on the diagram.

14. **D** **Phase diagram, normal boiling point**

Recall: Normal boiling point of a substance is the temperature at which vapor pressure equals the normal atmospheric pressure (1 atm).

Note: Point D is marked at 1 atm

Day 4: Answers and Explanations

15. **D** **Behavior of gases, Collision theory, rate of reaction.**

Note: Taking away molecules Y (decreasing [Y]) means fewer opportunity (decrease rate) of collision between X and Y

16. **A** **Writing reaction equation, equilibrium expression**

Step 1: Write equation for the reaction: $H_2 + I_2 <----> 2HI$

Step 2: Use x to represent moles of the substances that reacted

Let x = moles of H_2
x = moles of I_2 (because of 1 : 1 ratio in equation)

Step 3: Determine moles (concentration) of substances at equilibrium
$3 - x$ = moles of H_2
$3 - x$ = moles of I_2
$2x$ = moles HI moles H_2 reacted (x) + moles I_2 reacted (x) = 2x

Step 4: Write equilibrium expression using above equilibrium [ ]

$$K_c = \frac{[\text{products}]}{[\text{reactants}]} = \frac{[HI]^2}{[H_2] \cdot [I_2]} = \frac{\mathbf{2x^2}}{\mathbf{(3-x)^2}}$$

17. **C** **Nuclear decay, particle symbols**

Step 1: Write the symbols of emitted particles in the order given in question

beta	alpha	alpha	beta
$^{0}_{-1}e$	$^{4}_{2}He$	$^{4}_{2}He$	$^{0}_{-1}e$

Step 2: To get the top (mass) # of the stable nucleus:
Subtract the sum of top #s of particles (8) from 238. = **230**

To get the bottom (atomic) # of the stable nucleus:
Subtract the sum of bottom #s of particles (2) from 92 = **90**

$^{230}_{90}Th$

18. **B** **Half-reaction, reduction, oxidation number changes**

Recall: During reduction, there is a decrease in oxidation state of the particle being reduced.

Note: Half-equation for choice B is the only one that shows a decrease in oxidation number (Cl goes from 0 to -1)

Day 4: Answers and Explanations

19. **E** **Freezing point depression, molality, van't Hoff factor**

Recognize that based on information given, change in temperature, ΔT, must first be determined using the equation

$$\mathbf{\Delta T = i \cdot Kf \cdot m}$$

before the freezing point of the solution ($FP_{solution}$) can be determined.

Step 1: Calculate moles of solute, $AgNO_3$

$$\text{moles} = \frac{200\ g}{169.9\ g \cdot mol^{-1}} = 1.177\ mol$$

Step 2: Calculate molality (m)

$$m = \frac{\text{moles}}{\text{kg of solution}} = \frac{1.177\ mol}{1\ kg} = 1.177\ m$$

Step 2: Determine *i* (van't Hoff) factor for the solute, $AgNO_3$.

$AgNO_3$ ----> **1** Ag^+ and **1** NO_3^- = **2**

Step 3: Calculate ΔT

$\Delta T = i \cdot k_f \cdot m$

ΔT = **2** $(1.86\ ^\circ C \cdot m^{-1})(1.177\ m) = 4.38^\circ C$

Step 4: Calculate $FP_{solution}$

$FP_{solution} = FP_{water} - \Delta T$

$FP_{solution} = 0 - 4.38^\circ C = \mathbf{-4.38^\circ C}$

20. **C** **Energy, frequency, and wavelength in calculation**

Step 1: Calculate wavelength using equation below:

$$\lambda = \frac{c}{h} = \frac{3.00 \times 10^8\ m.s^{-1}}{3.00 \times 10^{14} \cdot s^{-1}} = 1.0 \times 10^{-6}\ m$$

Step 2: Calculate wavelength in nm

$$\lambda = 1.0 \times 10^{-6}\ m \times \frac{1.0 \times 10^9\ nm}{1\ m} = \mathbf{1.0 \times 10^3\ nm}$$

Day 4: Answers and Explanations

21. **B.** **Photoelectric effect, properties of elements**

Recall: Photoelectric is observed when the surface of a metal emits electrons as light shines on it.

Recall: Alkali metals, with one loosely held valance electron, most readily experience photoelectric effect

22. **C** **Solution, common-ion effect, van't Hoff factor**

Recall: If a solute containing a common-ion as a solution is placed in the solution, the solubility of the solute will be inhibited (common-ion effect)

Note: Na**Cl**, **Cu**NO_3, and Ca**Cl**$_2$ solutions each contain the same ion as $CuCl_2$ solute.

However, **Cu**Cl_2 will be least soluble in the solution with the greatest number of moles of the common-ion

Determine number of moles of the common-ion in each solution

0.02 m NaCl ------ > 0.02 moles Cl^- ion

0.02 m $CuNO_3$ ---- > 0.02 moles Cu^{+1}

0.02 m $CaCl_2$ ----- > 2(0.02 moles Cl^-) = **0.04 moles Cl-**

Note: $CaCl_2$ has the greatest moles of the common-ion.

23. **E** **Molecular structure, molecular bonding, hybridization**

Note: Pi bonding occurs in molecules where there are multiple bonding.

Note: CCl_4 is the only molecule listed with no multiple bonding

Day 4: Answers and Explanations

24. **B** **Solution, molarity , moles, and mass in calculations**

Step 1: Determine moles of NaCl

$$\text{moles} = \frac{15\ \text{g}}{58\ \text{g.mol}^{-1}} = 0.26\ \text{mol}$$

Step 2: Substitute into molarity equation and solve for Kg H_2O

$$\text{molarity} = \frac{\text{moles solute}}{\text{Kg of } H_2O}$$

$$0.75 = \frac{0.26}{X} \quad X = \mathbf{0.34\ Kg}$$

25. **D** **Hydrocarbons, molecular formulas, isomers, properties**

Note: The two formulas have the same number of atoms, therefore, are isomers.

Recall: Isomers are compounds with same molecular formula (same molar mass and same percent composition)

BUT

different structural formula (different compounds, different properties)

Day 5: Answers and Scoring Guidelines

(see important scoring guideline information on on page i)

1. **(10 points)**

Fluorine gas, $F_2(g)$, and a solid oxide, X_2O_8, are combined and heated in a 2.5 L flask to 721°C. The equilibrium reaction is shown in the balanced equation below.

$$X_3O_8(s) + 3F_2(g) \; <========> \; 3XO_2F_2(g) + O_2(g)$$

At equilibrium, the partial pressure of $F_2(g)$ is 0.83 atm and the partial pressure of $XO_2F_2(g)$ is 2.64×10^{-5} atm.

a) Calculate the partial pressure of $O_2(g)$ at 721°C,

Note: Since the partial pressure of the other product is given, use mole proportion to determine partial pressure of $O_2(g)$ (P_{O_2})

$P_{O_2} = 2.64 \times 10^{-5}$ atm $XO_2F_2 \times \frac{1 \text{ mol } O_2}{3 \text{ mol } XO_2F_2}$	**1 point** is earned for setup
$P_{O_2} = 8.80 \times 10^{-6}$ atm O_2	**1 point** for the correct P_{O_2}

b) Write the equilibrium expression, K_p, and calculate the value of the equilibrium constant for this reaction?

Recall: $K_p = \frac{(P_{products})}{(P_{reactants})}$

Write equilibrium expression from the equation $K_p = \frac{(P_{XO_2F_2})^3 (P_{O_2})}{(P_{F_2})^3}$	**1 point** is earned for writing equilibrium expression
Substitute factors into expression and solve $K_p = \frac{(2.64 \times 10^{-5})^3 (8.8 \times 10^{-6})}{(0.83)^3}$	**1 point** is earned for substitution
$K_p = \frac{1.62 \times 10^{-19}}{5.71 \times 10^{-1}}$ $K_p = 2.83 \times 10^{-19}$	**1 point** is earned for the correct K_p

c) Calculate the Gibb's Free energy change, ΔG°, for the reaction at 721°C.

Note: $\Delta G^\circ = -RT \ln Kp$ (See References Materials on Pg 340)

Note: T must be in Kelvin: 771°C + 273 = 994 K

ΔG° = R T ln Kp **$\Delta G^\circ = (-8.31\ J\ mol^{-1}\ K^{-1})(994\ K)(\ln 2.83 \times 10^{-19})$** $\Delta G^\circ = (-8.31\ J\ mol^{-1}\ K^{-1})(994\ K)(-42.7)$ **$\Delta G^\circ = 3.53 \times 10^5$ J/mol or 353 KJ/mol**	**1 point** is earned for setup **1 point** for the correct ΔG°

d) What will be the sign for the entropy change, ΔS°, for the reaction at 721°C. Explain your answer.

Recall: When entropy (disorder) increases , ΔS° is +

When entropy (disorder) decreases, ΔS° is -

ΔS° will be positive (+). According to the equation, entropy of the reaction increases because **4 moles of gaseous products are formed from 3 moles of reactants.**	**1 point** is earned for correct sign of ΔS° and explanation

e) What will be the sign for the enthalpy change, ΔH°, for the reaction at 721°C. Justify your answer.

Note: $\Delta H^\circ = \Delta G^\circ + T\Delta S^\circ$ (See References Materials on Pg 340)

ΔH° will always be positive (+) because **both ΔG° and $T\Delta S^\circ$ are positive**	**1 point** is earned for correct sign of ΔH° **1 point** is earned for correct explanation

Day 5: Answers and Scoring Guidelines

2. **(10 points)**

A pure sample of a nonvolatile compound containing only carbon, hydrogen and oxygen is analyzed. It is found to be a nonelectrolyte. Data from a combustion reaction of the compound was analyzed, and it is determined that the compound has mass percents of 31.57% C and 5.30% H.

(a) Determine the empirical formula of the compound.

Assume 100 g of the nonvolatile compound, Determine mass of each element Mass of C = 31.7 g Mass of H = 5.30 g Mass of O = 63.0 g (100 g – (31.7 g + 5.30 g) *Convert mass of each element to moles* moles = mass / molar mass moles of C = 31.7 g / 12 g.mol^{-1} = **2.639 mol C** mole of H = 5.30 g / 1.01 g.mol^{-1} = **5.2475 mol H** mole of O = 63.0 g / 16 g.mol^{-1} = **3.9375 mol O** *Determine mole ratio (subscript) of the elements by dividing each calculated mole above by the smallest of the moles (2.639 mol)* 2.639 mol C / 2.639 mol = C = 1 5.2475 mol H / 2.639 mol = H = 2 3.9375 mol O / 2.639 mol = O = 1.49 Multiply each mole by 2 to get whole number subscripts **$C_2H_4O_3$**	**1 point** is earned for calculating moles of the elements. **1 point** is earned for correctly calculating the empirical formula

(b) A 30.0 g sample of the compound is dissolved in 250.0 g of benzene C_6H_6. The freezing point of this solution is 1.46 °C. (The freezing point of benzene is 5.51 °C and K_f is 5.12 °C.kg^{-1}. mol^{-1})

(i) Determine the molecular mass of the substance.

Note: Based on information given, it is clear that moles of the nonvolatile compound must be determine in other to calculate the molecular mass (g/mol)

Determine change in freezing temperature from information given:

ΔT_f = $FP_{benzene}$ − $FP_{solution}$

ΔT_f = 5.51°C − 1.46°C = 4.05°C

Calculate molality (m) using equation below:

$\Delta T_f = i \cdot k_f \cdot m$

note: i (van't Hoff factor) is 1 because the solute is a nonelectrolyte)

$$m = \frac{T_f}{K_f} = \frac{4.05°C}{5.12\ C.m^{-1}} = 0.791\ m \text{ or } 0.791\ mol/Kg$$

Calculate moles of solute

$$m = \frac{\text{moles of solute}}{\text{Kg of solvent}}$$

moles = molality x Kg of solvent

moles = 0.791 mol/kg x .250 kg = **.198 mol solute**

1 point is earned for calculating moles of the solute

Calculate molecular mass of the substance

$$\text{Molecular mass} = \frac{\text{mass of solute}}{\text{moles of solute}}$$

$$\textbf{Molecular mass} = \frac{30\ g}{.198\ mol} = \textbf{152 g/mol}$$

1 point is earned for correctly calculating the molecular mass of the solute

Day 5: Answers and Scoring Guidelines

(ii) Determine the molecular formula for the compound.

Note: To calculate molecular formula, you need to know how many units of the empirical formula there are.

Determine mass of empirical formula (from part a)

$C_2H_4O_3$ = 2(C) + 4(H) + 3(O)

2(12) + 4(1) + 3(16) = 76 g

Find units of empirical

$$\frac{\text{Molecular mass}}{\text{Empirical mass}} = \frac{152\ g}{76\ g} = 2$$

Determine molecular formula by multiplying each subscript of the empirical formula by 2

$2(C_2H_4O_3) = C_4H_8O_6$

1 point is earned for correctly determining the molecular formula

(iii) Determine the mole fraction of the solute

Note: To determine mole fraction (X) of solute, you need to divide mole of solute ($C_4H_8O_6$) by moles of solvent (C_6H_6)

Calculate moles of solute ($C_4H_8O_6$) and of solvent (C_6H_6)

moles of $C_4H_8O_6$ = .197 mol $C_4H_8O_6$ see previous calculation for b(i)

$$\text{mole of } C_6H_6 = \frac{250.0\ g}{78\ g.\ mol^{-1}} = 3.205\ mol\ C_6H_6$$

1 point is earned for setup

Determine mole fraction (X) of solute $C_4H_8O_6$

$$X_{solute} = \frac{\text{moles of solute}}{\text{Total moles in solution}} = \frac{\mathbf{0.198}}{\mathbf{(0.198 + 3.205)}}$$

$$X_{solute} = \frac{0.198}{3.403} = \mathbf{0.058}$$

1 point is earned for correctly calculating the mole fraction of solute.

Day 5: Answers and Scoring Guidelines

(c) Determine the osmotic pressure of the solution if its density is 1.15 g/mL at 25.0 °C.

Note: Based on information known, osmotic pressure (Π), can be calculated using equation $\Pi = iMRT$ (Note i = 1)

Calculate Volume (V) from known information

$$V = \frac{\text{gram of solution}}{\text{density}} = \frac{280\text{ g}}{1.15\text{ g.mL}^{-1}} = 243\text{ mL}$$

Calculate Molarity (M)

$$M = \frac{\text{moles}}{\text{Volume}} = \frac{0.198\text{ moles}}{.243\text{ L}} = \mathbf{0.815\ M}$$

1 point is earned for calculating molarity

Calculate osmotic pressure (Π) using equation

$\Pi = MRT$

$$\Pi = \left(\frac{0.815\text{ mol}}{\text{L}}\right)\left(\frac{0.0821\text{ L. atm}}{\text{mol . K}}\right)\left(\frac{298\text{ K}}{1}\right) = \mathbf{19.9\ atm}$$

1 point is earned for correctly calculating the osmotic pressure

(d) Determine the vapor pressure (VP) of the solution at 25.0 °C. (The equilibrium vapor pressure of benzene is 95 mm Hg at 25.0 °C.)

Determine change in pressure of solvent using using Raoult's Law equation:

$\Delta P_{solvent} = (X\ solute)\ (P solvent)$

$\Delta p_{solvent} = (0.058)\ (95\ mmHg) = 5.51\ mm\ Hg$

Determine vapor pressure of the solution:

$VP_{solution} = P_{solvent} - P_{solvent}$

$\mathbf{VP_{solution}} = 95\ mmHg - 5.51\ mmHg = \mathbf{90.\ mmHg}$

1 point is earned for correctly calculating the vapor pressure

Day 5: Answers and Scoring Guidelines

(see important scoring guideline information on on page i)

1. **(15 points)**

(a) Sulfur trioxide gas is heated in the presence of solid calcium oxide.

Note: This is a combination (synthesis) reaction

(i) Balanced equation SO_3 + CaO -------> $CaSO_4$	**1 point** is earned for correct reactants **2 points are** earned for correct products **1 point** is earned for correctly balancing the equation

(ii) Draw the Lewis-dot structure for the product that forms

Ca^{2+} $\left[:\ddot{O}: \; :\ddot{O}:S:\ddot{O}: \; :\ddot{O}: \right]^{2-}$	**1 point** is earned for the correct Lewis structure

(b) Copper sulfate pentahydrate is heated over high heat.

Recall: Hydrates are ionic substances with attached water molecules.

Note: When heated, hydrates decompose to anhydrous and water.

(i) Balanced equation $CuSO_4 . 5H_2O$ ------> $CuSO_4$ + $5H_2O$	**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 5 grams of the hydrate was heated in a crucible to a constant mass, calculate the mass of the solid substance in the crucible.

Note: The solid substance in the crucible is the anhydrous, $CuSO_4$

To determine its mass in a 5-gram sample, you need to know the following: Molar mass of $CuSO_4.5H_2O$ = 250 g/mol

Mass of $CuSO_4$ in 250 g = 160 g $CuSO_4$

$5\text{ g } CuSO_4.5H_2O \times \frac{160\text{ g } CuSO_4}{250\text{ g } CuSO_4.5H_2O}$ **3.2 g $CuSO_4$**	**1 point** is earned for correctly calculating the mass

(c) Equal molar and volume of barium chloride and sodium carbonate solutions are mixed, resulting in the formation of a precipitate.

Note: This is a double replacement (ion exchange) reaction. Chlorine and sodium ions are spectator ions, therefore, are not included in the net equation.

(i) Balanced equation **Ba^{2+} + CO_3^{2-} -----> $BaCO_3$**	**1 point** is earned for correct reactants **2 points are** earned for correct products **1 point** is earned for correctly balancing the equation

(ii) Describe what will occur if the precipitate is dried and a few drops of a dilute hydrochloric acid are added. Explain.

Note: The equation for the reaction described above is as follows:

Bubbles of carbon dioxide gas (CO_2) will form. *or* **Precipitate ($BaCO_3$) will disappear.**	**1 point** is earned for the correct description.

Day 5: Answers and Scoring Guidelines

2. **(8 points)**

The reaction represented below is a reversible reaction.

$$HBr(g) + NH_3(g) <=======> NH_4Br(s)$$

(a) Predict the sign of the entropy change, ΔS, for the forward reaction. Explain your reasoning.

Entropy change will be negative. **- ΔS** Because: **Two moles of substances form one mole of substance, therefore, entropy is decreasing.** *or* **Gaseous reactants form solid product, therefore, entropy is decreasing.** *Recall:* Decreasing entropy = - ΔS	**1 point** is earned for the correct sign of entropy change. **1 point** is earned for explanation that is consistent with the sign of entropy change

(b) Predict the sign of the free energy change, ΔG, when the reaction reaches equilibrium.

ΔG = 0 **Zero** Free energy is Zero because the reaction is at equilibrium.	**1 point** is earned for the correct sign of entropy change.

(c) The forward reaction is spontaneous at low temperatures. When the temperature of the reaction is increased to a high temperature, how would the the sign of ΔG changes. Justify your answer.

Note: ΔG = ΔH - TΔS (See Reference Materials on pg 339)

Note: Since ΔS is negative (see a) and ΔH is also negative (spontaneous)

Δ G = - ΔH + TΔS (ΔG sign, therefore, depends on Temperature)

At low temperature, ΔG = - (spontaneous) because TΔS value is smaller than - ΔH value

At high temperature: **ΔG will change from negative (spontaneous) to positive (nonspontaneous)** because **At a high enough temperature, TΔS value will overcome (be greater than) - ΔH° value**	**1 point** is earned for the correct change of ΔG **1 point** is earned for correct justification

(d) Write an expression for calculating the value of the specific temperature referred to in part (c).

Note: ΔG = 0 at equilibrium $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ $0 = \Delta H^\circ - T\Delta S^\circ$ $T\Delta S = \Delta H$ $T = \frac{\Delta H}{\Delta S}$	**1 point** is earned for the correct expression

Day 6: Answers and Scoring Guidelines

(e) The system is allowed to reach equilibrium at the low temperature described in part (c). Additional solid $NH_4Br$is added to the reaction vessel. How will the value of the equilibrium constant be affected? Explain.

Adding more $NH_4Br(s)$ will not affect the equilibrium expression. because **a solid has constant concentration, therefore, its concentrations will not be included into equilibrium expression.**	**1 point** is earned for the correct effect **1 point** is earned for correct explanation that is consistent with the effect stated.

Day 7: Continue

24. The first part of the decay of plutonium-240 involves three alpha emissions followed by two beta emissions. What nuclide has been formed at this intermediate stage of the decay series?

(A) Radium-228
(B) Radium-224
(C) Actinium-228
(D) Thorium-232
(E) Thorium-228

25. What ions would you find in solution if potassium perchlorate was dissolved in water?

(A) KCl, O_2
(B) $K+, Cl^-, O_2^-$
(C) KCl, O_2^-
(D) K^+, ClO_4^-
(E) K^+, Cl^-, O_2^-

Day 7

STOP. Correct your answers and note how many correct **points**

Day 7: Answers and Explanations

Answers: Quick Check

1. **A**	2. **E**	3. **D**	4. **C**	5. **D**	6. **E**	7. **A**	8. **E**	9. **E**	10. **C**
11. **A**	12. **B**	13. **E**	14. **B**	15. **B**	16. **B**	17.**C**	18.**D**	19. **D**	20. **D**
21. **D**	22. **C**	23. **B**	24. **E**	25. **D**					

Answers and Explanations

Questions 1 through 3: Rate Law, Order of reactions

1. **A** *Recall:* In first Order reactions, the sum of all exponents of reactants in the rate law equation must add up to 1.

   Note: in Choice A equation: rate = $k[X]^1$ Sum of exponents is **1**

2. **E** *Recall:* A reaction is second order in respect to a specified reactant if the exponent of the reactant is a 2 in the rate law equation.

   Note: In Choice E equation: rate = $k[X]^2[Y]^2$ exponent of Y is **2**.

3. **D** *Recall:* In Third Order reactions, the sum of all exponents of reactants in the rate law equation must add up to 3.

   Note: In Choice D equation: rate = $k[X]^2[B]^1$ Sum of exponents is **3**

Questions 4 through 7: Nuclear particles behavior and properties

4. **C** *Recall:* Gamma has the highest energy of all radiations.

5. **D.** *Note:* This is a fact about another use of X-ray
   When focused on a solid, X-ray produces diffraction pattern that can revealed the crystalline structure of the solid.

6. **E** *Note:* Ozone, O_3, which is found in the upper atmosphere, can be broken down by chlorine (Cl_2). UV light, which is also found in upper atmosphere, catalyzes this reaction.

7. **A** *Recall:* Symbol for an alpha particle is ^4_2He

8. **E** **Formula writing, naming**

Note: Formulas for all other choices are incorrectly named. Correct names for these formulas are given below

CsCl: Cesium chloride CBr_4: Carbon tetrabromide
Fe_2O_3: Iron (III) oxide NO_2: Nitrogen dioxide or

9. **E** **Atomic Structure, Electron configuration, quantum numbers**

Recall that a ground state configuration is correctly written for an atom when the followings are the case:

. The available sublevels for the atom are correctly represented
. The sublevels are filled in order from lowest energy to highest energy (1s 2s 2p 3s 3p 4s 3d 4p 5s 4d.....)
. Each sublevel has the correct number of electrons it should have according to certain rules
. The sum of electrons in the configuration is equal to the atomic number (or number of protons) of the atom

Note: The ground state configuration $1s^2 2s^2 2p^6 3p^5$ given for P (15 electrons) is incorrect because one of the available sublevels (3s) is missing in the configuration

10. **C** **Thermodynamic, Enthalpy change calculation, Heat of formation**

Recognize that ΔH° for this reaction can be calculated using the equation

$$\Delta H^\circ = \sum \Delta Hf^\circ_{products} - \sum \Delta Hf^\circ_{reactants}$$

Step 1: Write a balance equation for the reaction to determine the correct moles of reactants and products.

$$\mathbf{2}C_2H_6(g) + \mathbf{7}O_2(g) \text{ -----> } \mathbf{4}CO_2(g) + \mathbf{6}H_2O(g)$$

Step 2: Substitute values from the Table in ΔH equation

$$\Delta H^\circ = \sum \Delta Hf^\circ_{products} - \sum \Delta Hf^\circ_{reactants}$$
$$\Delta H^\circ = [\mathbf{4}(-393) + \mathbf{6}(-251)] - \mathbf{2}(-84)$$
$$\Delta H^\circ = -1572 - 1506 + 168$$
$$\Delta H^\circ = -3078 \text{ kJ for 2 moles of } C_2H_6$$

Step 3: Adjust the calculated KJ for 1 mole of C_2H_6 :
- 2910 KJ / 2 mol = **−1455 kJ/mol**

Day 7: Answers and Explanations

11. **A** **Periodic Trend, atomic structure,**

Recall: Atomic radius decreases from Left to right (Increasing atomic number) due to the increase in nuclear charge (number of protons)

12. **B** **Reaction of acids, property of gases**

Recognize that based on the properties of the gas described in the question, the gas is likely carbon dioxide, CO_2.

Determine: Based on its formula, $NaHCO_3$ (of all the choices listed) is likely to react with an acid to produce CO_2

Note: The net ionic equation for this reaction is:

$$H^+ + HCO^- \text{ -------> } CO_2 + H_2O$$

13. **E** **Rate law, rate constant, rate calculation, writing equation**

Step 1: Write the correct reaction equation based on info given:

$$CH_3CHO(g) \text{ ------> } CH_4(g) + CO(g)$$

Step 2: Write the rate law based on information given and the equation

rate = $k[CH_3CHO]^2$ as stated, rate is 2nd order and depends on $[CH_3CHO]$

Step 3: Determine k (rate-specific constant) at the old concentration

$$k = \frac{\text{rate}}{[CH_3CHO]} = \frac{0.10 \text{ mole} \cdot L^{-1} \cdot \sec^{-1}}{(0.010 \text{ mole } L^{-1})^2}$$

$$k = 1.0 \times 10^3 \text{ L} \cdot \text{mole}^{-1} \sec^{-1}$$

Step 4: Determine rate at the new $[CH_3CHO]$

$$\text{rate} = k[CH_3CHO]^2 = \left(\frac{1.0 \times 10^3 \text{ L}}{\text{mole} \cdot \sec}\right) \times \left(\frac{0.050 \text{ mole}}{\text{L}}\right)^2$$

$$\text{rate} = \frac{2.5 \times 10^1 \text{ mole}}{\text{L.sec}} \quad \text{or} \quad \mathbf{2.5 \text{ mol / (L . sec)}}$$

Day 7: Answers and Explanations

14. **B** **Dipole moments, molecular polarity, molecular structures**

Recall: Dipole moment refers to degree of polarity of a molecule. The more polar the molecule, the higher its dipole moment.

Note: HCl is the most polar (biggest difference in electronegativity values) of the five choices given.

N_2 and Cl_2 are nonpolar. Their dipole moments are zero.

15. **B** **Lewis structures, organic compounds, condensed formula**

Note: Structure B is the only one matches the condensed formula

16. **E** **Gas equilibrium constant calculation, moles in reaction**

Recognize that based on information given, this gas equilibrium problem can be solved using the equation

$$K_p = K_c \times (RT)^{\Delta n}.$$

Step 1: Convert 350°C to Kelvin (Temp in all gas laws must be in Kelvin)

K = °C + 273

K = 350 °C + 273 = 623 K

Step 2: Determine Δn (difference in moles of products to reactants)

2 $NO_2Cl(g)$ <--------> **2** $NO_2(g)$ + **1** $Cl_2(g)$

Δn = **3** moles of products - **2** moles of reactants = **1**

Step 3: Substitute factors into equation and solve for K_p

$K_P = K_c \times (RT)^{\Delta n}$ *($R = 0.0821\ L.atm.mol^{-1}.K^{-1}$)*

$K_p = 8.90 \times (0.0821 \times 623)^1 =$ **455.**

17. **C** **Percent composition by mass**

Recognize that the quickest way to determining the answer to this problem is to divide the mass of H in each formula by the molar mass of the formula, and see which one is equal to 1/5th or 20%.

Note: in CH_3 $\dfrac{\text{mass of H}}{\text{mass of } CH_3} = \dfrac{3}{15} = \dfrac{1}{5} = 20\%$ H

18. **D** *Note:* I and II are measurements of the activation energy.

Recall: A catalyst lowers activation energies of a reaction.

Day 7: Answers and Explanations

19 **D** **Partial pressure – mole fraction calculation**

Recognize that based on information given, the equation below can be used to setup and solve the problem for P_{NO2}

$$P_{NO2} = \left(\frac{\text{mole of } NO_2}{\text{Total mole}}\right) \times P_{total}$$

$$P_{NO2} = \left(\frac{4.5\ \text{mol}}{6.0\ \text{mol}}\right) \times 8.0\ \text{atm} = \mathbf{6.0\ atm}$$

20. **D** **Number of dissolved particles – Vapor pressure relationship**

Recognize that based on the diagram and information given, each substance that is placed on top of the mercury creates vapor pressure (VP) that pushes down on the mercury in the manometer.

Note: Since the volume (ml) and molality (m) of the substances in all three manometers are equal, the difference in the push on mercury (as represented by the diagram) is dependent upon the amount of vapor pressure created by each substance.

Lowest mercury level (M) = Greatest push = Highest VP substance

Highest mercury level (K) = Least push = Lowest VP substance

Determine highest VP substance (in M)

M has **water** : because it is pure and produces **no dissolved** particles.

Determine lowest VP substance (in K)

K has **NaCl**: Because it is ionic and produces **2 dissolved particles** (**1**Na+ and **1**Cl-)

L (intermediate VP) has **glucose** because it is molecular, and produces **1 dissolved** particle

Day 7: Answers and Explanations

21. **D** **Oxidation numbers in a formula**

Recall: Total charge in a neutral formula must equal 0

Note the followings about the given formula: $[Cr(NH_3)_6](NO_3)_3$

NH_3 is neutral : Total Charge of 6 NH_3 = 0

NO_3 - ion = -1: Total charge of 3 NO_3^- = -3

Cr must have a total positive charge of **+3** for all charges to equal 0

Note: Since there is just 1 Cr; Oxidation # of Cr = **+3**

22. **C** **Mass–Volume calculation**

Step 1: Determine moles of 150 g $CaCO_3$ consumed

$$\text{moles } CaCO_3 = \frac{\text{mass}}{\text{molar mass}} = \frac{150\text{ g}}{100\text{ g.mol}^{-1}} = \textit{1.50 moles}$$

Step 2: Determine volume of CO_2 through mole proportion in the balanced equation

$$\text{Volume} = 1.5\text{ mol } CaCO_3 \times \frac{1\text{ mol } CO_2}{1\text{ mol } CaCO_3} \times \frac{22.4\text{ L}}{1\text{ mol } CO_2}$$

Volume of CO_2 = **34 L**

Day 7: Answers and Explanations

23. **B** **Change in voltage, Nernst equation, electrochemistry**

Recognize that most of the choices given can be eliminated based on the fact that the information given for these choices will not affect voltage.

Eliminate Choices A, C and E because based on reasoning, mass, color, nor type of salt bridge will not affect voltage.

Eliminate Choice D because both half-cells containing the solutions are in the same area, therefore, the temperature of the solutions should be about the same.

Note: Choice B is left as the correct answer. This can be proven by considering $[Zn^{2+}]$ and $[Cu^{2+}]$ in Nernst equation.

$$E = E^0 - \frac{RT}{nF} \ln Q \qquad \textit{Recall:}\ Q = \frac{[\text{products}]^m}{[\text{reactants}]^n} = \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

According to above equations, voltage depends on [ ]

24. **E** **Nuclear decay series, nuclear particles**

Step 1: Write the symbols of emitted particles in the order given

alpha	alpha	alpha	beta	beta
^4_2He	^4_2He	^4_2He	$^0_{-1}e$	$^0_{-1}e$

Step 2: Write the symbol for plutonium – 240

$$^{240}_{94}Pu$$

Step 3: Subtract the sum of the top (mass) # of emitted particles from 240 : 240 – **12** = 228

Subtract the sum of the bottom (charge) # of emitted particles from 94 : 94 – **4** = 90

Note: 90 is the atomic number. The nuclide is Thorium-228

25. **D** **Composition of a chemical compound, solution, cation and anion**

Note: Potassium perchlorate is an ionic compound with the formula $KClO_4$.

Recall: When an ionic compound is placed in water, it dissolves to produce cation (K+) and anion (ClO_4-)

Day 8: Answers and Scoring Guidelines

(see important scoring guideline information on on page I)

1. **(10 points)**

The reaction $2NO_2(g) + Cl_2(g) \text{ -----> } 2NO_2Cl(g)$ was studied at 20°C and the following data were obtained:

(a) Write the rate law for the reaction.

Note: Based on equation given, rate expression will be as follows:

$\text{rate} = k[NO_2]^n[Cl_2]^m$ **n** = order with respect to $[NO_2]$
m = order with respect to $[Cl_2]$
n and m need to be determined

Determine order ***m*** by setting up rate ratio between experiment 2 and 1 since $[NO_2]$ is constant. Substitute data for both experiments from table into rate expression above.

$$\frac{\text{rate2}}{\text{rate1}} = \frac{k\,(0.100M)^n\,(0.010\ M)^m}{k\,(0.100\ M)^n\,(0.0050\ M)^m} = \frac{2.70 \times 10^{-7}\ \text{mole/(L . sec)}}{1.35 \times 10^{-7}\ \text{mole/(L . sec)}}$$

$$2^m = 2$$

$$m = 1$$

1 point is earned for calculating **m**

Determine order ***n*** by setting up rate ratio between *experiment 3 and 2 since $[Cl_2]$ is constant.* Substitute data for both experiments from table into rate expression above.

$$\frac{\text{rate 3}}{\text{rate2}} = \frac{k\,(0.200\ M)^n\,(0.010\ M)^m}{k\,(0.100M)^n\,(0.010\ M)^m} = \frac{5.40 \times 10^{-7}\ \text{mole/(L . sec)}}{2.70 \times 10^{-7}\ \text{mole/(L . sec)}}$$

$$2^n = 2$$

$$n = 1$$

1 point is earned for calculating **n**

Write rate law by substituting m and n into rate expression:

$\text{rate} = k[NO_2]^1[Cl_2]^1 = \mathbf{k[NO_2][Cl_2]}$

1 point is earned for the correct rate law

(b) What is the overall order for the reaction? Explain.

Recall: Overall order of a reaction is the sum of all the orders.

2 **Overall order of a reaction is the sum of all the orders:** m + n = 1 + 1 = 2	**1 point** is earned for the correct sum with explanation.

(c) Calculate the rate-specific constant, *k*, including the correct units.

Note: Since the rate was determined in part (a), *k* can be determine by substituting data from one of the experiments into the rate law, and solve for k

Rearrange rate law for k rate = $k[NO_2][Cl_2]$ $k = \frac{\text{rate}}{[NO_2][Cl_2]}$	
Substitute data for experiment 1, and solve for k $k = \frac{1.35 \times 10^{-7} \text{ mole/(L . sec)}}{(0.100 \text{ mole/L})(0.005 \text{ mol/L})}$ k = **2.7×10^{-4} L / (mole . sec)**	**1 point** is earned for correctly calculating the k value.
Note: Since temperature is the same for all three experiments, and the reaction is first order with respect to both reactants, data from any of the three experiments can be used to calculate *k*. The value for *k* will be the same	**1 point** is earned for the correct unit

(d) In Experiment 3, what is the initial rate of decrease of $[Cl_2]$?

Note: The initial rate of decrease of a reactant is proportional to the initial rate of increase of the products.

Write rate change equation based on the equation given $2NO_2(g) + Cl_2(g) \text{ -----> } 2NO_2Cl(g)$ $\frac{-d[Cl_2]}{dt} = \frac{1}{2}\frac{d[NO_2Cl]}{dt}$ *Note:* - sign indicates that the change of Cl_2 is in opposite direction (decreasing) in respect to the direction of change of NO_2Cl (increasing). *Note:* ½ indicates that moles of Cl_2 is half that of NO_2Cl in the balanced equation. They are at a 1 : 2 ratio.	**1 point** is earned for the correct setup to calculate initial rate of decrease of Cl_2
Substitute rate for experiment 3 and solve for $[Cl_2]$ $-[Cl_2] = \frac{5.40 \times 10^{-7} \text{ mol / (L . sec)}}{2}$ $[Cl_2]$ = **-2.7×10^{-7} mol / (L . sec)**	**1 point** is earned for answer that is consistent with the setup.

(e) Based on the equation given for this reaction:

(i) Propose mechanisms for the reaction that is consistent with the rate law expression you found in part (a).

Note: The sum of the steps of the mechanism must equal the balanced equation.

The sum of the mechanism must be consistent with the experimentally-determined rate law.

Propose mechanisms (steps) and determine the sum of the equations Step 1: $NO_2(g)$ + $Cl_2(g)$ -----> $NO_2Cl(g)$ + ~~$Cl(g)$~~ Step 2: ~~$Cl(g)$~~ + $NO_2(g)$ -----> $NO_2Cl(g)$ Sum: **$2NO_2(g)$ + $Cl_2(g)$ -----> $2NO_2Cl(g)$** *Note:* The sum of the mechanisms is the same as the equation *Note:* The rate law for the rate-determining step is consistent with the experimentally-determined rate law: rate = $k[NO_2][Cl_2]$ for both	**1 point** is earned for the correct mechanisms

(ii) Which is the rate determining step in the proposed mechanism

Step 1 *or* **$NO_2(g)$ + $Cl_2(g)$ -----> $NO_2Cl(g)$ + $Cl(g)$** is the slow rate determining step	**1 point** is earned for mentioning step 1

Day 8: Answers and Scoring Guidelines

2. **(10 points)**

The setup below shows the electrolysis of water that is at 25°C and 1 atm.

The electrolysis process was allowed to proceed for 4.37 minutes while the voltage source supplies a constant 1.213 amperes of current.

a) Write a balance equation for the decomposition of water during the electrolysis process.

$2H_2O(l)$ -----> $O_2(g)$ + $2H_2(g)$	**1 point** is earned for a correct balanced equation

b) Write a balance half-reaction equation for the reaction at the cathode.

Recall: Reduction (gaining of electrons) occurs at the cathode.

The half-reaction must represent reduction.

$2H_2O(l)$ + 2e- -----> $H_2(g)$ + 2OH-(aq)	**1 point** is earned for the correct and balanced half-reaction equation

c) Calculate the amount of electrical charge, in coulombs, that passes through the solution during the time period mentioned.

Recall: 1 ampere = 1 coulomb/sec

1.213 amperes = 1.213 coulomb/sec

Set up using factor-labeling electrical charge = **4.37 min** x $\frac{\textbf{60 sec}}{\textbf{1 min}}$ x $\frac{\textbf{1.213 coul}}{\textbf{sec}}$ **electrical charge = 318 coulombs**	**1 point** is earned for setup **1 point** is earned for the correct answer

d) The half-reaction that occurs at the anode is:

$2H_2O\,(l)$ ----> $O_2\,(g)$ + $4H^+\,(aq)$ + $4e^-$

(i) Calculate the number of moles of $O_2\,(g)$ produced at the anode.

Note: 1 mole of e- = 96500 coulombs (see Reference Materials pg 340)

Set up using factor-labeling involving mole ratio mole of $O_2(g)$ = **318 coul** x $\frac{\text{1 mol e-}}{\text{96500 coul}}$ x $\frac{\text{1 mol } O_2}{\text{4 mol e-}}$ **moles of $O_2(g)$ = 8.24 x 10^{-4} moles O_2**	**1 point** is earned for setup **1 point** for correct moles of O_2

(ii) Calculate the volume, in milliliters, of $O_2(g)$ produced during the electrolysis process.

Note: Since temperature (25°C) and pressure (1 atm) are known, use the ideal gas law equation to set up and solve.

$PVo_2 = no_2 RT$ Note: T must be in Kelvin
25°C + 273 = 298 K
n = moles of O_2 (see (i))
R = gas constant

Rearrange ideal gas law equation $Vo_2 = \frac{no_2 RT}{P}$ *Substitute values into equation and solve* $Vo_2 = \frac{(8.24 \times 10^{-4}\ \text{mol})\ (0.0821 \frac{\text{L.atm}}{\text{mol.K}})\ (298\ \text{K})}{1\ \text{atm}}$ **Vo_2 = 0.0202 L = 20 mL**	**1 point** for setup using ideal gas equation **1 point** for the correct volume of O_2

(iii) Explain why the volume of $H_2(g)$ collected is different from the volume of $O_2(g)$ collected during the same time.

Note: The balanced equation for the reaction

$2H_2O(l)$ ----------> $O_2(g)$ + $2H_2(g)$

The volume of $O_2(g)$ produced is less than that of the $H_2(g)$ because, according to the balanced equation, **2 moles of H_2 gas are produced to only 1 mole of O_2 gas**	**1 point** for explanation that includes mole ratio of O_2 to H_2

e) Identify another substance, including its phase, which is also collected in both test tubes along with $O_2(g)$ and $H_2(g)$.

H_2O (g) **Water vapor**	**1 point** for the correct answer

Day 9: Answers and Scoring Guidelines

(see important scoring guideline information on on page i)

1. **(15 points)**

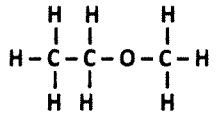
(a) Methanol and acetic acid are mixed and then gently warmed.

Note: This is an esterification reaction

Recall: In esterification, an ester and water are produced by reacting an organic acid with alcohol

(i) Balanced equation CH_3OH + CH_3COOH -----> CH_3COOCH_3 + H_2O *methanol* *acetic acid* *ester* *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) Draw the structure of the organic compound formed

	**1 point** is earned for the correct structure of the ester

(b) Solid potassium carbonate is added to 2 *M* sulfuric acid.

(i) Balanced equation K_2CO_3 + 2H+ -------> CO_2 + H_2O + 2K+	**1 point** is earned for correct reactants **2 points are** earned for correct products **1 point** is earned for correctly balancing the equation

(ii) How many molecules of the acid will react with 27.6 grams of the potassium carbonate.

Recall: 1 mole = 6.02×10^{23} molecules

Determine moles of K_2CO_3 in 27.6 g $27.6\ g\ K_2CO_3 \times \frac{1\ mole\ K_2CO_3}{138\ g\ K_2CO_3} = 0.2\ mol\ K_2CO_3$ *Determine moles of the acid based on proportion* $0.2\ mol\ K_2CO_3 \times \frac{2\ mol\ H+}{1\ mol\ K_2CO_3} = 0.4\ mol\ H+$ *Calculate # of molecules in 0.4 moles of H+* molecules = $0.4\ (6.02 \times 10^{23}) = \mathbf{2.4 \times 10^{23}}$	**1 point** is earned for correctly calculating the number of molecules

(c) A pellet of sodium hydroxide is added to a solution of iron (III) sulfate.

Note: This is a double replacement (ion-exchange) reaction
Note: Sodium and sulfate ions are both spectator ions. Therefore, they are not included in the equation.

(i) Balanced equation $\mathbf{3OH^-} + \mathbf{Fe^{3+}} \text{ -----> } \mathbf{Fe(OH)_3}$	**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 type of chemical bonding is or are present in a formula unit of iron (III) sulfate.

Ionic and Covalent bonding or **Ionic and polar** bonding	**1 point** is earned for the correct bond types

Day 9: Answers and Scoring Guidelines

2. **(8 points)**

The first three ionization energies (I_1, I_2, and I_3) for magnesium and Argon are given in the following table:

(a) Write the complete electron configurations for magnesium and argon.

Mg $\mathbf{1s^2 2s^2 2p^6 3s^2}$ Ar $\mathbf{1s^2 2s^2 2p^6 3s^2 3p^6}$	**1 point** is earned for the correct configurations for both Mg and Ar.

(b) Draw the Lewis electron-dot diagrams for Mg and Ar.

Recall: Lewis electron-dot diagram shows symbol of atom and dots equal to the number of valance electrons

Mg : **: Ar :**	**1 point** is earned for the correct Lewis electron-dots for both Mg and Ar.

(c) Based on the data table information:

(i) State one similarity found in ionization energies for both atoms.

Recall: Ionization energy is the energy to remove the most loosely bound electron from an atom

Energy to remove the 1^{st} through 3^{rd} electrons increases steadily. **The first ionization energy is the lowest.** **The third ionization energy is the highest.**	**1 point** is earned for any one correct similarity

(ii) Explain why the difference between the 2nd and 3rd ionization energies of Mg is much greater than the difference between the 2nd and 3rd ionization energies of Ar. Include both Mg and Ar.

In magnesium, the 3rd ionization energy is over 5 times as much as the 2nd ionization because: **the 3rd electron to be removed from Mg is located in the second energy level (closer to the nucleus) while the 2nd electron to be removed is located in the third energy level (farther from the nucleus)** In argon, the energy difference is only twice as much because **both the 3rd and 2nd electrons to be removed are located in the same (third) energy level.**	**1 point** is earned for the correct explanation

(d) If chlorine gas is passed into separate containers of heated magnesium and heated argon, explain what compounds (if any) might be formed, and explain your answer in terms of the electron configurations of these two elements.

$MgCl_2$, magnesium chloride	**1 point** is earned for the correct compound
Mg will react with chlorine because **Mg only has two valance electrons, and will readily give them** up to chlorine to form a stable octet valance configuration. Ar will not react (no product will form) with chlorine because **argon already has a complete valance shell configuration and is stable.**	**1 point** is earned for correct explanation that includes Mg and Ar.

Day 9: Answers and Scoring Guidelines

(e) An unknown element, Y, has the following three ionization energies:

Atom	I_1 *(KJ/mol)*	I_2 *(KJ/mol)*	I_3 *(KJ/mol)*
Y	496	4560	6912

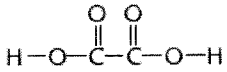
On the basis of the ionization energies given, what is the formula and name of the compound produced when chlorine reacts with element Y. Explain your reasoning.

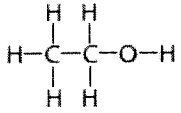
NaCl , sodium chloride	**1 point** is earned for stating NaCl
Element Y is likely sodium for the following reasons: The I_1 of Y is much smaller than the I_1 of Mg indicating that the 1st electron of Y is located farther from the nucleus than the 1st electron of Mg. Y must be an element that is bigger than Mg. **Na** is bigger than Mg. The I_3 of Y is less than twice the I_2 of Y indicating that both the 2nd and 3rd electrons are located in the same energy level. This is the case with most alkali metals. *Note:* If Y was Ca, its I_3 would be much more greater than its I_2 since the 3rd electron would be in an energy level that is closer to the nucleus than that of the 2nd electron.	**1 point** is earned for correct explanation

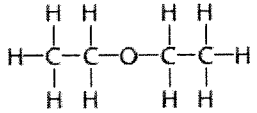
Day 10: Continue

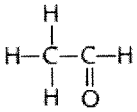
Questions 46 through 50 refer to types of organic compound below.

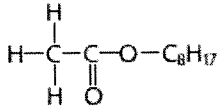
(A) alcohol
(B) aldehyde
(C) carboxylic acid
(D) ester
(E) ether

46. 

47. 

48. 

49. 

50. 

Day 10

STOP. Correct your answers and note how many correct **points**

Day 10: Answers and Explanations

Answer: Quick Check

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

Answers and Explanations

Questions 1 through 5: Le Chatelier's Principle, equilibrium reactions

1. **A** *Note:* N_2O in the equation is a reactant.
Note: To reestablish equilibrium from adding more reactant, the added reactant must be consumed.
Relate: Speeding up in the forward direction (***shift to the right***) allow the reaction to consume the added reactant.

2. **A** *Note:* O_2 in the equation is a product
Note: To reestablish equilibrium from removal of a product, the reaction will make more of that product.
Relate: Speeding up in the forward direction (***shift to the right***) allows the reaction to produce more of the removed product.

3. **B** *Note:* A decrease in volume means pressure is increased on the reaction.
Recall: To reestablish equilibrium from a pressure increase, more of the substances on the side that has fewer total moles must be produced.
Note: In the equation, the reactant side has fewer total moles (2)
Relate: A decrease in volume speeds up the reverse reaction (***shift to the left***) in order to produce more N_2O

4. **A** *Note:* The reaction has + ΔH value. This means :
Forward reaction is endothermic. Heat is absorbed as a reactant.
Reverse reaction is exothermic. Heat is released as a product
N_2O_2 + 163 KJ < ======= > $2N_2 + O_2$

Recall: To reestablish equilibrium from increased temperature, endothermic (forward) reaction is favored (***Shift to the right***) so the added heat can be consumed.

5. **C** *Recall:* Addition of a catalyst lowers the activation energies for both the forward and reverse reactions. As a result, both the forward and reverse reactions are increased equally, and there is ***no shift in either direction.***.

Questions 6 through 8: Electron configuration, atomic structure

6. **C** *Recall:* The electron configuration of a paramagnetic element must have a sublevel with at least one unpaired e-

Note: The configuration $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^4$

↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑ ↑

has **two unpaired** electrons in the 3p sublevel.

7. **D** *Note:* Both potassium ion (K+) and chlorine ion (Cl-) have 18 e- . Both have the same configuration $1s^2 2s^2 2p^6 3s^2 3p^6$, which is the same as that of the noble gas element closest to them (Ar)

8. **A** *Note:* The atom of this element (Ne) has only 2 electron shells. All of the others have 3 or more shells.

9. **E** **Solution – Beer's Law relationship**

Recall: According to Beer's law, absorbency is directly proportional to the concentration of a solution.

Note: To measure absorbance, a spectrometer is needed. An appropriate reagent must be a colored solution

Determine: $Ni(NO_3)_2$, which contains a transition metal, is the only colored solution listed.

10. **D** **Solubility Guideline, precipitate**

Note: A Precipitate is formed when an insoluble compound is formed from mixing two solutions.

Note: Mixing NaCl with $Pb(NO_3)_2$ produces **$PbCl_2$**(s).

Recall solubility guidelines: Chloride ion is mostly soluble, EXCEPT when it combines with **Pb^{2+}**, Ag^+, or Hg^{2+}

Day 10: Answers and Explanations

11. **A** **Boiling point–concentration relationship, van't Hoff factor**

Recall: The degree of boiling point elevation is related to the number of moles of ions in the solution. Solution with the greatest number of moles of ions will have the highest boiling point.

Note: Based on information given, the number of moles of ions in each solution can be calculated using the equation:

Moles of ion = Molarity x Volume x i (van't Hoff factor)

(A)	**Moles in KNO_3**	**=**	**0.50**	**x**	**.250**	**x**	**2 ions**	**= .250 moles**
(B)	Moles in $Al(NO_3)_3$ =		0.10	x	.400	x	4 ions	= .160 moles
(C)	Moles in NH_4NO_3 =		0.20	x	.500	x	2 ions	= .200 moles
(D)	Moles $AgNO_3$	=	0.30	x	.300	x	2 ions	= .180 moles
(E)	Moles in $Ni(NO_3)_2$ =		0.10	x	.200	x	3 ions	= .060 moles

Note: Choice A solution has the highest total moles of ions, therefore, highest boiling point

12. **A** **Ion concentration in solution**

Note: Highest NO_3^- concentration can be calculated for each solution using the equation:

$[NO_3^-]$ = M x moles of NO_3^- ions

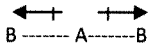
(A)	**$[NO_3^-]$ in KNO_3**	**=**	**0.50**	**x**	**1**	**=**	**. 50 M**
(B)	$[NO_3^-]$ in $Al(NO_3)_3$	=	0.10	x	3	=	. 30 M
(C)	$[NO_3^-]$ in NH_4NO_3	=	0.20	x	1	=	. 20 M
(D)	$[NO_3^-]$ in $AgNO_3$	=	0.30	x	1	=	. 30 M
(E)	$[NO_3^-]$ in $Ni(NO_3)_2$	=	0.10	x	2	=	. 20 M

Note: Choice A has highest $[NO_3^-]$

13. **E** **Factors affecting molecular shape**

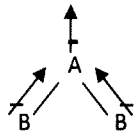
Note: Shape of AB_2 molecule can be determined if dipole moments of the molecule are known.

If dipole moments cancel out:



The molecule is linear and nonpolar

If dipole moments add (net dipole)



The molecule is bent and polar

Note: Non of the other properties (alone) will be enough to determine the shape of the molecule

14. **A** **Nuclear decay, emission particles**

Note: The difference between $^{19}_{8}O$ and $^{19}_{9}F$ is $^{0}_{-1}e$ (beta)

Note: Since this is a decay, the answer is beta emission, NOT, electron capture

15. **D** **Interpreting potential energy diagram**

Note: To determine the incorrect statement, consider each choice and eliminate those that are true of the energy diagram.

Note: **Eliminate Choice A.** True b/c product energy is higher than reactant's

Eliminate Choice B. True b/c Points 1 and 3 represent intermediates

Eliminate Choice C . True b/c the transitional point is measured at the activated complex

Eliminate Choice E. True b/c increasing energy at point 2 will result in a longer reaction pathway, hence, slower rate.

Note: **Choice D is false:** Equilibrium concentration of products depends on the initial concentration of reactants and final concentration of products only.
Therefore, raising energy of intermediate 3 will not affect the equilibrium concentration of the product

16. **C** **Energy change and pressure calculation, thermodynamic**

Recall : Recognize that based on information given, change in energy, ΔE , can be calculated using the First Law of thermodynamics equation below.

$\Delta E = q + w$ *Note:* $w = -(P_{ext} \times \Delta V)$

Rewrite equation, substitute factors into equation, and solve

$\Delta E = q - (P_{ext} \times \Delta V)\ 101.32\ J.L^{-1}.atm^{-1}$

$\Delta E = 505.64\ J - (2.0\ atm \times 1\ L)\ 101.32\ J.L^{-1}.atm^{-1}$

$\Delta E = 505.64\ J - 202.64\ J =$ **303.00 J**

17. **C** **Interpreting reaction equation**

Note: In the reaction, NH_4+ has 1 more H+ (proton) than NH_3

Recall: A species in a reaction with one more H^+ than another is the conjugate acid

Note: Non of the other choices is true or can be infer about the reaction based on just the equation given

18. **B** **Molecular shapes-hybridization relationship**

Recall the relationship between electron pairs, electron geometry and hybridization:

Electron pairs	*electron geometry*	*hybridization*
2	*linear*	*sp*
3	**trigonal planer**	$\boldsymbol{sp^2}$
4	tetrahedral	sp^3
5	trigonal bipyramidal	sp^3d
6	octahedral	sp^3d^2

19. **A** **Interpreting Gibb's free energy**

Recall: Free energy $\Delta G = \Delta H - T\Delta S$

Note: Since ΔH is + and ΔS is - as stated in the question, $\Delta G = +\Delta H + T\Delta S = +\Delta G$ (nonspontaneous) regardless of temperature (T)

20. **E** **Common-ion effect, solubility**

Note: Silver hydroxide (AgOH) is a base.

Relate: Its solubility will be hindered the most when placed in a solution with the highest OH- concentration (highest pH)

21. **B** **Quantum numbers interpretation**

Note: The set of numbers listed in the choices represents n, l, m_l, *and* m_s, respectively

Recall what each quantum number represents:

n	= shells	n value range:	1	to	7
l	= subshells	l value range:	0	to	$(n-1)$
m_l	= orbitals	m_l value range:	$-l$	to	$+l$
m_s	= spin	m_s values:	$-1/2$	or	$+1/2$

Note: Based on information above, m_l value should never be greater than l

Note: In Choice B, the m_l value (1) is greater than the l value (0). Therefore, B has the impossible set of quantum numbers.

22. **B** **Percent yield calculation, equation writing**

Step 1: Write a balanced equation for the reaction described.

$$4CH_4 + F_2 \text{ --------> } 2CH_3CH_2F + 3H_2$$

Step 2: Determine theoretical yield of 1-fluoroethane from 96-g CH_4.

$$96\text{ g } CH_4 \times \frac{1\text{ mol } CH_4}{16\text{ g } CH_4} \times \frac{2\text{ mol } CH_3CH_2F}{4\text{ mol } CH_4} \times \frac{48\text{ g } CH_3CH_2F}{1\text{ mol } CH_3CH_2F} = 144\text{ g } CH_3CH_2F$$

Step 3: Calculate percent yield

$$\%\text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

$$\%\text{ yield} = \frac{96}{144} = \frac{2}{3} \times 100 = \mathbf{66\%}$$

Day 10: Answers and Explanations

23. **B** **Total pressure–mole fraction relationship**

Recognize that based on information given, total pressure (P_{total}) can be calculated using mole fraction equation

$$P_{total} = X_A P_A + X_B P_B \qquad X = \text{mole fraction}, \; P = \text{partial pressure}$$

Rewrite equation, substitute factors from question, and solve.

$$P_{total} = \left(\frac{\text{mole of A}}{\text{total moles}}\right) P_A + \left(\frac{\text{mole of B}}{\text{total moles}}\right) P_B$$

$$P_{total} = \left(\frac{1.50}{7.0}\right) 75\text{ mm Hg} + \left(\frac{5.50}{7.0}\right) 25\text{ mm Hg}$$

P_{total} = **35.7 mm Hg**

24. **A** **Solution properties**

Note: When solute particles (in this question, potassium and chloride ions) are present in water, they interact and interfere with certain physical and chemical properties of water.

Recall: The present of solute in water allows the solution to have: **Higher boiling point, lower freezing point, and lower vapor pressure**

25. E **Percent composition**

Step 1: Write the correct formula for calcium hydroxide: $Ca(OH)_2$

Step 2: Determine molar mass of $Ca(OH)_2$

Molar mass = 1 Ca + 2 O + 2H

Molar mass = 1(40) + 2(16) + 2(1) = 74 g/mol $Ca(OH)_2$

Step 3: Determine mass of Oxygen in 148 g $Ca(OH)_2$

$$\text{Mass of O} = 148\text{ g } Ca(OH)_2 \times \frac{32\text{ g O}}{74\text{ g } Ca(OH)_2} = \mathbf{64\text{ g O}}$$

26. A **Equilibrium expression**

Recall: $k_{eq} = \frac{[\text{Products}]}{[\text{Reactants}]} = \frac{[CO_2]^2}{[CO]^2}$

Note: Solids are not included in the equilibrium expression because they have constant concentrations

The exponents are the coefficients of the substances in the balanced equation.

27. C **Understanding Titration process**

Note: **Choice C** is the only correct statement. This statement will be true for all acid-base titration graphs.

Note: **Choice A** is false because the equivalent point of weak acid – strong base titration occurs at pH above 7.

Choice B is false because pH does not depends on indicator

Choice D is false because a basic salt will be produced, resulting in a sharp increase in pH

Choice E is false because [H+] is equal to the ionization constant, K_a, at the half-equivalence point; NOT at the equivalence point.

28. E **Phase change – Energy – Entropy – Free energy relationship**

Note the followings about the phase change of water given.

$H_2O(g)$ --------> $H_2O(l)$

Gas to liquid = **Exothermic** (heat is released) **ΔH = -**

Gas to liquid = **Entropy decreases** (less disorder) **ΔS = -**

Gas to liquid = **Spontaneously** (occurs by itself at room temp) **ΔG = -**

Day 10: Answers and Explanations

29. B **Half-reaction interpretation**

Note the followings about the half-reaction equation:

$AuCl_4^- + 3e^- \text{--------} > Au + 4Cl^-$

It represents reduction as written (e- is a reactant).

Gold changes from +3 to 0 (a reduction of oxidation state)

Recall: Reduction occurs at cathode **Choice B**

Note: Chloride ion does not change its oxidation state. (Eliminate D & E)

30. C **Coulombs law, factor-labeling**

Recognize that based on information given, grams of gold produced can be calculated by setting up factor-labeling. When all units are crossed out, what's left is the correct setup.

$$\frac{4.0\ C}{s} \times \frac{30\ min}{1} \times \frac{60\ s}{1\ min} \times \frac{1\ mol\ e^-}{96{,}500\ C} \times \frac{1\ mol\ Au}{3\ mol\ e^-} \times \frac{197\ g\ Au}{1\ mol\ Au}$$

$$\frac{\cancel{4.0\ C}}{\cancel{s}} \times \frac{\cancel{30\ min}}{\cancel{1}} \times \frac{\cancel{60\ s}}{\cancel{1\ min}} \times \frac{\cancel{1\ mol\ e^-}}{96{,}500\ \cancel{C}} \times \frac{\cancel{1\ mol\ Au}}{\cancel{3\ mol\ e^-}} \times \frac{197\ g\ Au}{\cancel{1\ mol\ Au}}$$

31. C **Atomic radius – nuclear charge relationship, ionic size comparison**

Recall: The size (radius) of atoms depends on factors such as:
Number of electron shells
Number of electrons
Number of protons (nuclear charge)

Note: All of the ions listed are isoelectronic, meaning they have the same number of electrons (10), therefore, same number of electron shells.

Relate: The difference in size of these ions depends mostly on their nuclear charges. The greater the nuclear charge, the smaller the radius. Therefore:

Order of increasing size = Order of decreasing nuclear charge

Smallest radius : Mg^{2+} (+12 nuclear charge)
F^- (+9 nuclear charge)
Largest radius : O^{2-} (+8 nuclear charge)

Day 10: Answers and Explanations

32. **E** **Completing equation, Solubility rules, precipitate**

Recall: Precipitate is formed when an insoluble compound is formed from mixing two solutions.

Determine product for each reaction, then use solubility rules to determine which product is insoluble

(I) $HBr + Ca(OH)_2 \text{ -----> } H_2O + CaBr_2$ *(soluble)*

(II) $Pb(NO_3)_2 + LiI \text{ ------> } LiNO_3$ *(soluble)* $+ PbI_2$ *(insoluble)*

(III) $(NH_4)_3PO_4 + MgCl_2 \text{ ----> } NH_4Cl$ *(soluble)* $+ Mg_3(PO_4)_2$ *(insoluble)*

Note: Both II and III produce insoluble (precipitate) products

33. **E** **Le Chatelier's Principle**

Note: All five reactions involve gaseous reactants and products.

Recall: Equilibrium concentration of substances in a gaseous reaction WILL NOT change when the total moles of reactants and products are equal.

Note: Reaction for Choice E is the only one listed with total moles of reactants and products being equal (3 moles on each side).

34. **C** **Equation writing, mass – mole calculation in equation**

Step 1: Write a correct balanced equation for the reaction described.

$4Al + 3O_2 \text{ -------> } 2Al_2O_3$

Step 2: Use factor- labeling to solve by utilizing mole ratio in equation

$$\text{mole of } O_2 = 25.5 \text{ g } Al_2O_3 \times \frac{1 \text{ mol } Al_2O_3}{102 \text{ g } Al_2O_3} \times \frac{3 \text{ mol } O_2}{2 \text{ mol } Al_2O_3}$$

mole of O_2 = **0.375 mol**

Day 10: Answers and Explanations

35. **B** **Oxidation of acids, acid formulas, acid strength**

Note: When an oxyacid (acid with oxygen) is oxidized, the number of oxygen of the acid increases. The new acid formed is stronger.

Note: When an oxyacid has the maximum number of oxygen that it could have, that acid can't be oxidized any further.
Ex: H_2SO_3 can be oxidized to form H_2SO_4
But
H_2SO_4 can't be oxidized any further.

Note: Of all the acids listed, only HNO_2 (a weaker acid) can be oxidized further (to HNO_3, a stronger acid)

-36. **C** **Enthalpy change/Energy change in equations, thermodynamics**

Recognize that based on information given, the equation
$\Delta H = \Delta E + P\Delta V$ (law of thermodynamic)
must be considered in order to correctly determine the reaction in which ΔH and ΔE are nearly equal.

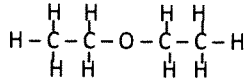
Note: Based on the equation, ΔH and ΔE will be equal only when $P\Delta V$ is equal to Zero. This will be the case if ΔV (change in volume) of the system is zero.

Relate: A reaction will have ΔV equal to zero if there are no gaseous substances involve in the reaction.

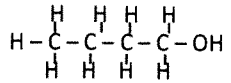
Note: Choice C is the only reaction of those listed in which there no gaseous substances are involved.

37. **B** **Comparing properties of organic compounds, isomers**

Recognize that one way to choose the correct statement about the boiling points of these two substances is to correctly draw and compare their structures and formulas.



$C_4H_{10}O$
diethyl ether



$C_4H_{10}O$
1-butanol

Note: Based on the structures and formulas, these two substances are isomers. (Eliminate Choice E)

Note: Based on the structures, diethyl ether is nonpolar (symmetrical) while 1- butanol is polar (asymmetrical).

Recall: Polar substances have higher boiling point than nonpolar.

Day 10: Answers and Explanations

38. **D** **Molar mass – rate relationship, comparing rate of gases**

Recall: Rate of effusion of gases is related to their molar masses (M) according to the equation below:

$$\frac{V_1}{V_2} = \sqrt{\frac{M_2}{M_1}}$$

Note: The mass of H_2 = 2 g

Relate: A gas that travels at $^1/_3$ the speed of H_2 must have a molar mass that is 9 times as great as the molar mass of H_2

Note: H_2O has a molar mass of 18 g (9 times as great as 2 g)

39. **C** **Bond angle-Molecular shape relationship**

Note that drawing the Lewis diagram for the nitrate ion is one way of determining its shape, as well as the N – O bond angle.

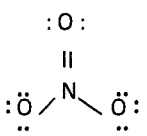
Determine number of electrons available for bonding in NO_3^-, and then draw the Lewis structure for NO_3-

N = 1(5) = 5 e-

O = 3 (6) = 18 e-

-1 = 1 e-

Total e- = 24 e-



Note: The shape of NO_3^- is trigonal planer. Bond angles of this shape is always 120°

40. **D** **Titration data interpretation, sources of errors**

Note: Only the NaOH volume for the first sample is, in terms of titration, significantly different from the rest.

Note: The only reasonable explanations is that the pipet that was used to transfer the acetic acid in the first sample was not rinsed with the acid.

Note: All other errors listed will not affect the volume of the titrant (NaOH)

Day 10: Answers and Explanations

41. **C** **Entropy Change calculation**

Step 1: Recall entropy change, ΔS°, equation

$$\Delta S^\circ = \Sigma^\circ S \text{ products} - \Sigma^\circ S \text{ reactants}$$

Step 2: Substitute numbers from table into equation. Be sure to take number of moles of substances in the balanced equation into account .

$$\underset{}{\mathbf{3}\,Mg + Al_2O_3} \qquad \underset{}{\mathbf{2}\,Al(s) + \mathbf{3}\,MgO}$$

$$\Delta S^\circ = \left[\mathbf{3}\,(33.0) + 51.0\right] - \left[\mathbf{2}\,(28.0) + \mathbf{3}\,(27.0)\right]$$

$$\Delta S^\circ = 150 - 137 = \mathbf{13.0\ J/(mole.K)}$$

42. **D** **Flame test**

Recall your flame test colors: Lithium always red

43. **B** **Percent abundance of isotopes, Atomic mass calculation**

Note: Since the atomic mass (63.55) is closer to the mass of ^{63}Cu, the percent of ^{63}Cu will be greater than that of ^{65}Cu

Eliminate choice C and D (these choices reflect greater % of ^{65}Cu)

Note: One way to quickly solve this problem is to set up the problem as follows:

Let x = decimal fraction of percent of ^{63}Cu

then 1 – x = decimal fraction of percent of ^{65}Cu

Recall: Atomic mass is the sum of the products of decimal fraction x mass number of the isotopes

$$63(x) + 65(1 - x) = 63.55$$

$$63x + 65 - 65x = 63.55$$

$$2x = 1.45$$

$$x = .73 \approx \mathbf{70\%\ of\ ^{63}Cu}$$

Day 10: Answers and Explanations

44. **D** **Equilibrium expression calculation, dissociation**

Recognize that K_a can be determined from equilibrium expression.

Step 1: Write equation for the dissociation of $HC_2H_3O_2(aq)$

$$HC_2H_3O_2\,(aq) \;<=====>\; H+\,(aq) \;+\; C_2H_3O_2\text{-}(aq)$$

Step 2: Write equilibrium expression for above equation

$$K_a = \frac{[H+]\,[C_2H_3O_2\text{-}]}{[HC_2H_3O_2]}$$

Step 3: Determine concentrations:

$[H+] = -\log pH = -\log(2) = .01$ M

$[C_2H_3O\text{-}] = [H+] = .01$ M (based on mole ratio of **1**H+ : **1**$C_2H_3O_2$-)

$[HC_2H_3O] = 1.0$ M (concentration of a weak acid like acetic stays nearly unchanged b/c weak acids dissociate very slightly)

Step 4: Substitute [ ] into equation and solve for Ka

$$K_a = \frac{(0.01)\;(0.01)}{1.0} = .0001 = \mathbf{1.0 \times 10^{-4}}$$

45. **B** **Percent calculation**

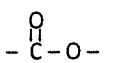
$$\%\text{ dissociation} = \frac{[\text{Part}]}{[\text{whole}]} \times 100$$

$$\%\text{ dissociation} = \frac{.01\text{ M}}{1.0\text{ M}} \times 100 = \mathbf{1.0\,\%}$$

Day 10: Answers and Explanations

Questions 46 through 50: Organic functional groups

Recall the functional group associated with each class of organic compound listed as choices

class	functional group
(A) alcohol	- OH
(B) aldehyde	
(C) carboxylic acid	
(D) ester	
(E) ether	– O –

46. **C** *Note:* Structure given contains a *carboxylic acid* functional group

47. **A** *Note:* Structure given contains an *alcohol* functional group

48. **E** *Note:* Structure given contains an *ether* functional group

49. **B** *Note:* Structure given contains an *aldehyde* functional group

50. **D** *Note:* Structure given contains an *ester* functional group

Day 11: Answers and Scoring Guidelines

(see important scoring guideline information on on pg i)

1. Hypochlorous acid, HOCl, is a weak acid that ionizes in water, as shown in the equation below

$$HOCl(aq) \quad <====> \quad H^+(aq) + OCl^-(aq)$$
$$K_a = 2.9 \times 10^{-8}$$

(a) Calculate the $[H^+]$ in a HOCl solution that has a pH of 5.24.

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

$[H^+] = 10^{-pH}$ $[H^+] = 10^{-5.24} = \mathbf{5.75 \times 10^{-6}}$	**1 point** is earned for correctly calculating the $[H^+]$

(b) Using information provided above:

(i) Write the equilibrium expression (K_a) for the ionization of HOCl in water.

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

$K_a = \dfrac{[H^+][OCl^-]}{[HOCl]}$	**1 point** is earned for the correct equilibrium expression

(ii) Calculate the concentration of HOCl(*aq*) in a HOCl solution that has $[H^+]$ equal to 2.4×10^{-5} M.

Note: $[OCl^-] = [H^+]$ because they are at 1 : 1 ratio in the equation.

$[HOCl] = \dfrac{[H^+][OCl^-]}{K_a}$ $[HOCl] = \dfrac{\mathbf{(2.4 \times 10^{-5}\ M)(2.4 \times 10^{-5})}}{\mathbf{2.9 \times 10^{-8}}}$ $[HOCl] = \mathbf{= 2.0 \times 10^{-2}\ M}$	**1 point** is earned for the correct setup to calculate [HOCl] **1 point** is earned for [HOCl] that is consistent with the setup

(c) A solution of $Ba(OH)_2$ is titrated into a solution of HOCl.

(i) Calculate the volume of 0.200 M $Ba(OH)_2(aq)$ needed to reach the equivalence point when titrated into a 75.0 mL sample of 0.150 M HOCl(aq).

Recall: (moles of OH-)(M_b) (V_b) = (moles of H+) (M_a) (V_a)

Note: $Ba(OH)_2$ contains 2 moles of OH-
HOCl contains 1 mole of H+

Substitute values from question into equation and solve for volume of $Ba(OH)_2$ (V_b) (moles of OH-)(M_b) (V_b) = (moles of H+) (M_a) (V_a) (2) (0.200 M) V_b = (1) (0.150 M) (0.075 L) **V_b = 0.0281 L $Ba(OH)_2$**	**1 point** is earned for the correct volume

(ii) Write the equilibrium expression, K_b, for the titration reaction that occurs.

Note: $OCl^- + H_2O$ ------ > $HOCl + OH^-$

$K_b = \dfrac{[HOCl]\,[OH^-]}{[OCl^-]}$	**1 point** is earned for the correct expression

(iii) Calculate k_b of OCl^-

Recall:

$K_w = K_b \times k_a$

$k_b = \dfrac{K_w}{K_a} = \dfrac{1.0 \times 10^{-14}}{2.9 \times 10^{-8}} = \mathbf{3.4 \times 10^{-7}}$	**1 point** is earned for the correct k_b

(iv) Calculate the pH at the equivalence point.

Note: Once [OH-] is known, pH can be calculated.

Note: [OH-] can be calculated by substituting values from the question and calculations (i – iii) into the k_b equation

Calculate [OCl-] $[OCl^-] = \dfrac{\text{moles of } OCl^-}{\text{Total volume}} = \dfrac{\text{Molarity} \times \text{Volume}}{(V_a + V_b)}$ $[OCl^-] = \dfrac{(0.150\ mol.L^{-1})\,(0.075\ L)}{(0.075\ L + 0.0281\ L)} = 0.109\ M$ *Determine concentrations* [OH-] = X [HOCl] = X because they at a 1 : 1 ratio *Substitute [ ] into k_b expression and solve for X)* $K_b = \dfrac{[HOCl]\,[OH^-]}{[OCl^-]}$ $3.4 \times 10^{-7} = \dfrac{X^2}{0.100}$ $1.93 \times 10^{-4} = X = [OH^-]$	**1 point** is earned for setup that leads to calculation of [OH-] or [H+]
Calculate pOH $pOH = -\log [OH^-] = -\log (1.93 \times 10^{-4}) = 3.72$ *Calculate pH* **pH = 14 - pOH = 14 - 3.71 = 10.28**	**1 point** is earned for correctly calculating the pH

(d) $HClO_3$ is a stronger acid than HOCl. Account for this fact in terms of molecular structure.

Note: In both HOCl and $HClO_3$, H – O bond must be broken for the acids to ionize.

The weaker the H – O bond, the easier it is for the acid to ionize, and the stronger the acid.

$HClO_3$ is a stronger acid than HOCl because the H – O bond in $HClO_3$ is weaker than the H – O bond in HOCl. This is due to the fact that the additional O atoms that are bonded to the central Cl atom in $HClO_3$ weakens its H – O bond.	**1 point** is earned for the correct explanation.

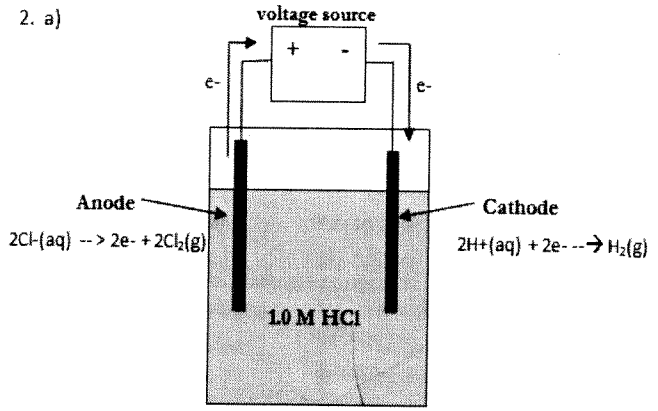
Day 11: Answers and Scoring Guidelines

2. Electrical current is passed through a 1.0*M* solution of HCl(*aq*) by means of two nonreactive electrodes immersed into the solution, with the electrodes connected to opposing terminals of a voltage source.

(8 points)

(a) (i) Sketch and label the diagram of the electrolytic cell, (ii) labels for anode and cathode, (iii) write half- reaction occurring at each electrode, and (iv) direction of electron flow.

2. a)



Your diagram will vary greatly from the one above. Points are based on the followings:

(i) A correctly sketched diagram must have: **one cell (beaker) , a voltage source, two bars connected to the positive and negative ends of the voltage source and submerged in HCl solution.**	**1 point** for a correct diagram
(ii) Metal bar connected to + is labeled **"Anode"** and Metal bar connected to – is labeled **"Cathode"**	**1 point** for correctly labeled anode and cathode
(iii) Half-reaction at + electrode: **$2Cl^-(aq) \rightarrow 2e^- + Cl_2(g)$** and Half-reaction at - electrode **$2H^+(aq) + 2e^- \rightarrow H_2(g)$**	**1 point** for correct and balanced half-reactions at + and - electrodes
(iv) **Direction of e-** is shown from bar at + to bar at –	**1 point** for correct direction of e-

(b) 4.5 amperes of current is applied to the reaction for 20 minutes.

(i) How many Coulombs pass through the cell during that time?

Note: 4.5 amp = 4.5 coulomb/sec (1 amp = 1 coulomb/sec)

20 minutes = 1.2×10^3 sec

Note: $I = \frac{q}{t}$ (see Reference Materials pg 340)

Charge (q) = time (t) x current (I) Charge (q) = 1.2×10^3 sec x $\frac{4.5 \text{ coulombs}}{\text{sec}}$ Charge (q) = **5.4×10^3 coulombs**	**1 point** is earned for the correct charge

(ii) How many moles of electrons pass through the cell during that time?

Note: 1 mole of e- = 96500 coulombs (Faraday's constant)

moles of e- = charge x Faraday's constant moles of e- = 5.4×10^3 coulombs x $\frac{1 \text{ mole e-}}{96500 \text{ coulombs}}$ moles of e- = **5.6×10^{-2} mol**	**1 point** is earned for correct moles of e-

iii) If the system is at STP, how much volume of hydrogen gas is produced during that time?

Recall: 1 mole of gas = 22.4 L at STP

Determine moles of H_2 using mole proportion in the half-reaction equation: **$2H^+ + 2e^- \text{ --------} > H_2$** 5.6×10^{-2} mol e- x $\frac{1 \text{ mole } H_2}{2 \text{ moles e-}}$ = **0.028 moles H_2**	**1 point** is earned for calculating moles of H_2
Calculate volume of H_2 Volume of H_2 = moles of H_2 x 22.4 L/mol Volume of H_2 = 0.028 mol x 22.4 L/mol = **0.627 L**	**1 point** is earned for correct volume of H_2

Day 11: Answers and Scoring Guidelines

(c) What happens to the pH of the HCl solution as current passes through it within the cell? Justify your response with explanation.

Recall: pH is related to H+ concentration of a solution.

Note: As current passes through the solution, H+ ion of the HCl solution is converted to H_2.
As a result, [H+] decreases.

pH increases	**1 point** is earned for indicating that **p**H increases
pH increases because **the H+ concentration decreases as the electrolytic processes is taking place.** A decrease in H+ resulted in an increase in phi	**1 point** is earned for explanation that is consistent with change in pH indicated.

Day 12: Answers and Scoring Guidelines

(see important scoring guideline information on on pg i)

1. **(15 points)**

(a) Dinitrogen oxide is mixed with water?

Recall: Nonmetal oxide combines with water to produce an acid.

Note: The acid (HNO_3) formed is left in an ionized form because nitric acid is a strong acid. Strong acids ionize completely.

(i) Balanced equation N_2O_5 + H_2O -------> $2H^+$ + $2NO_3^-$ *nonmetal oxide* *water* *acid*	**1 point** is earned for correct reactants **2 points are** earned for correct products **1 point** is earned for correctly balancing the equation

(ii) Would the pH of the solution that is produced less than 7, equal to 7, or greater than 7. Explain your answer.

The pH would be less than 7 because an acidic solution is formed.	**1 point** is earned for the correct pH with explanation

(b) Carbon dioxide gas is heated in the presence of solid magnesium oxide.

Note: This is a combination reaction in which a salt is formed from a basic and an acid anhydrides.

(i) Balanced equation CO_2 + MgO ------ > $MgCO_3$ *Basic anhydride* *Acid anhydride* *Salt*	**1 point** is earned for correct reactants **2 points are** earned for correct products **1 point** is earned for correctly balancing the equation

(ii) How many grams of magnesium oxide must completely react with 11 grams of the carbon dioxide?

Determine moles of CO_2 in 11 g. $11\ g\ CO_2 \times \frac{1\ mole\ CO_2}{44\ g\ CO_2} = 0.25\ mol\ CO_2$ *Determine moles of MgO based on proportion* $0.25\ mol\ CO_2 \times \frac{1\ mol\ MgO}{1\ mol\ CO_2} = 0.25\ mol\ MgO$ *Calculate grams of MgO* $0.25\ mol\ MgO \times \frac{40\ g\ MgO}{1\ mol\ MgO} =$ **10 g MgO**	**1 point** is earned for correctly calculating the grams of magnesium oxide

(c) Small pieces of aluminum are added to a solution of copper(II) sulfate.

Note: This is a single replacement redox reaction
Note: Sulfate ions is unchanged in the reaction. Therefore, it is not included in the equation.

(i) Balanced equation 2 Al + 3 Cu^{2+} -----> 2 Al^{3+} + 3 Cu	**1 point** is earned for correct reactants **2 points are** earned for correct products **1 point** is earned for correctly balancing the equation

(ii) Write the correct oxidation and reduction half equations for the reaction that occurs.

Oxidation-half: Al ------ > Al^{3+} + $3e^-$ *Reduction-half:* Cu^{2+} + $2e^-$ ----> Cu	**1 point** is earned for the correct oxidation and reduction half equations

Day 12: Answers and Scoring Guidelines

2. Use your knowledge of redox and electrochemistry to answer the following questions. **(8 points)**

(a) What is the function of a salt bridge in a galvanic cell, and why is it necessary in order the cell work?

Recall: A salt bridge connects the two compartments of a galvanic cell

A salt bridge **allows anions (-) and cations (+) to flow** between the two compartments. A salt bridge is required for a galvanic cell to work because **the flow of the ions maintains cell neutrality .**	**1 point** is earned for correct function **1 point** is earned for correct explanation.

(b) Explain why, when a piece of nickel is placed in hydrochloric acid, a reaction occurs, but when a piece of copper wire is placed in hydrchloric acid, no reaction occurs.

Recall: Spontaneous redox reaction occurs when potential (E) is +.

A reaction occurs between the nickel (Ni) and HCl solution because the reaction has a positive potential (+E). According to the Table of Reduction Potentials: E_{oxi} Ni ----> Ni^{2+} + 2e- = + 0.25 V E_{red} 2 H+ + 2e- -----> H_2 = 0.00 V E for reaction = **+ 0.25 V**	**1 point** is earned for correctly explaining (or showing) why reaction occurs with Ni
A reaction did not occur between the copper wire (Cu) and the HCl solution because the reaction has a negative potential (-E). E_{oxi} Cu ----> Cu^{2+} + 2e- = - 0.34 V E_{red} 2 H+ + 2e- -----> H_2 = 0.00 V E for reaction = **- 0.34 V**	**1 point** is earned for correctly explaining (or showing) why no reaction occurs with Cu

Day 12: Answers and Scoring Guidelines

(c) Cu^{2+} + Pb(s) -----> Cu(s) + Pb^{2+}

(i) Give the standard cell potential for the reaction above.

Recall: $E_{cell} = E_{oxi} + E_{red}$

Note: Use Table of Reduction Potential on pg 338 to get E for each half-reaction. Be sure to reverse the sign for oxidation half.

E_{oxi} Pb ----> Pb^{2+} + 2e- = +0.13 V E_{red} Cu^{2+} + 2e- -----> Cu = + 0.34 V E_{cell} for reaction = **+0.47 V**	**1 point** is earned for the correct cell potential

(ii) What happens to the cell potential in (i) when $[Pb^{2+}]$ is increased? Explain.

The E_{cell} will decrease because $[Pb^{2+}]$ is a product, and increasing [ ] of a product forces the reaction to shift left (favors the reverse reaction). This decreases the voltage that is produced by the cell.	**1 point** is earned for the correct change in E_{cell} with explanation

(iii) What is the value of ΔG° for the cell?

Note: $\Delta G^\circ = -nFE$ (See Reference Materials on pg 339)

Note: n = moles of electrons = 2 (see equations in (i))
F = Faraday's constant = 96500 C/mol (see Reference materials)

$\Delta G^\circ = - nFE$ ΔG° = -(2) (96500 C/mol)(+0.47 V) ΔG° = **- 90710 C.V/mol** **- 90710 J/mol or 90.7 KJ/mol**	**1 point** is earned for correct setup **1 point** is earned for correctly calculating ΔG°

Day 13: Answers and Explanations

Answers : Quick Check

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

Answers and Explanations

Questions 1 through 5: Phases of matter, particle arrangements

1. **D** *Recall:* A *supercritical fluid* is a material that has properties of both a liquid and a gas at high temperature and pressure conditions that is above the critical point..

   Note: As a gas, a supercritical fluid can diffuse.

   As a liquid, a supercritical fluid can dissolve other substances.

2. **B** *Note:* This a definition of a *metallic* bonding

3. **E** *Recall:* A*morphous solids* are noncrystalline solids in which particles (atoms and molecules) are not orderly arranged as it would be in real solids.

   Note: Examples of amorphous solids include gel, glass, and certain polymers like plastic.

4. **C** *Recall:* *Plasma* , the fourth phase of matter, is achieved by a substance when its gaseous particles are ionized under extreme heat.

   Note: Plasma can diffuse like a liquid, but their properties are unique and unusual because they have ionic charge.

5. **A** *Recall:* *Crystalline solids* have tightly and geometrically packed particles that does not allow for any movement within the structure. As a result, particles of a crystalline solid can only vibrate around a fixed point.

Questions 6 through 9: Characteristics of common substances

6. **E** *Recall:* An oxidizing agent is also a substance that can be easily reduced.

   Note: Both nitric acid (HNO_3) and potassium permanganate ($KMnO_4$) can be easily reduced.

   Recall: $KMnO_4$ contains a transitional metal (Mn) which has different color depending on its oxidation state.

7. **A** *Recall:* An oxidizing acid reacts with certain metals metal to produce oxides rather than hydrogen gas.

   $Cu + 4\,H^+ + 2\,NO_3^- \text{-------} > Cu^{2+} + 2\,NO_2 + 2\,H_2O$

   Note: Of the two acids listed, nitric acid, is the oxidizing acid. Other oxidizing acids includes perchloric acid ($HClO_4$) and Iodic acid (HIO_3)

8. **D** *Note:* Galvanizing is a method of protecting building materials by coating the materials with zinc. The zinc will corrode, (oxidized) instead of the building material.

9. **A** *Recall:* Acid rain is composed of H_2SO_4 (sulfuric acid).

   H_2SO_4 is formed in a two step process:

   Step 1: $SO_2 + O_2 \text{--------} > SO_3$

   Step 2: $SO_3 + H_2O \text{-------} > H_2SO_4$

Questions 10 through 13: Reaction types

10. **D** *Note:* In the reaction shown, two reactants combined to form one product.

11. **A** *Note:* In the reaction shown:
    I^- is oxidized to I_2^0 (oxidation number increases)
    and
    Fe^{3+} is reduced to Fe^{2+} (oxidation number decreases)

12. **B** *Note:* In the reaction shown, an acid (CH_3COOH) and a base (NaOH) neutralize each other to form water.

13. **E** *Note:* In the reaction shown, C_3H_8 (propane) is burned (combust) in the presence of oxygen.

Question 14 through 16: Acid-base reactions. Identifying species

14. **D** *Note:* BF_3 (a trivalent compound) does not have octet of electrons. This compound only has six electrons in the valance shell and therefore, is capable of accepting electrons from a Lewis Base.

Note: In the reaction shown, BF_3 is accepting electrons from F-.

Recall: An electron acceptor (BF_3) is defined as a Lewis acid.

BF_3 + F^- -----> BF_4
Lewis acid *Lewis base* *has a complete octet*

15. **E** *Note:* In the reaction shown, CN- is donating electrons to Cu^{2+} to form a complex ion.

Recall: An electron donor (CN-) is defined as a Lewis base.

$Cu^{2+}(aq)$ + $4CN^-(aq)$ -----> $Cu(CN)_4^{2-}(aq)$
Lewis acid *Lewis base* *complex ion*

16. **C** *Note:* In the reaction, H_3O+ is formed from H_2O. This only occurs because the H_2O accepts a proton (H+) from the $HC_2H_3O_2$.

Recall: A proton acceptor (H_2O) is defined as a Bronsted-Lowery base.

$HC_2H_3O_2(aq)$ + $H_2O(aq)$ ---> $C_2H_3O_2^-(aq)$ + $H_3O^+(aq)$
Bronsted-Lowery acid *Bronsted-Lowery base* *conjugate base* *conjugate acid*

Day 13: Answers and Explanations

17. **C** **Completing equation**

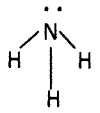
Note: This is a double replacement (ion-exchange) reaction.

Note: Choice B and C contain the same atoms. However, Choice C is correct because the correct formulas for the products, silver chloride (AgCl) and potassium nitrate (KNO_3), are correctly written.

18. **C** **Lewis structures of formulas, lone pair electrons**

Note: If necessary, draw the Lewis electron-dot structures for all five compounds, and note which has one pair of unshared electrons.

Note: The Lewis structure for NH_3 (ammonia) below has one pair of unshared electrons on the nitrogen.



19. **B** **Half-life calculation, nuclear decay**

Step 1: Determine number of half-life periods (n) from times.

The number of half-life periods (n) is the number of times the given mass of the radioisotopes decayed in half.

$$n = \frac{\text{length of time}}{\text{half-life}} = \frac{36 \text{ hrs}}{12 \text{ hrs}} = 3$$

Step 2: Cut 4 mg (original mass) in half as many times as n (3)

½ (**4 mg**) = 2 mg

½ (2 mg) = 1 mg

½ (1 mg) = **0.5 mg**

20. **B** **Lattice energy, ionic bond strength comparison**

Recall: Lattice energy is defined as the energy needed to separate the ions of an ionic compound.

Note: The stronger the ionic bond, the greater the lattice energy needed to separate the ions

Note: The strength of ionic bond depends on two factors: ***The Size of the charges*** and ***the size (radii) of the ions.***

Consider and compare charges of the ions to determine which has the greatest lattice energy

The size of charge: The greater the charge of the ions, the stronger the bond, the greater the lattice energy.

Of the compounds listed: MgO contains ions (Mg^{2+} and O^{2-}) with the greatest charges.

MgO, therefore, has the strongest ionic bond, and also the **highest lattice energy** of the three.

Note: Since the two remaining compounds (LiF and KBr) contain ions of the same charges (+1 and -1), other factor must be considered in order to determine which of the two has a higher lattice energy

Consider and compare the size of the ions to determine which has the smaller radius:

The size of ionic radius: The smaller the radius, the stronger the bond, the greater the lattice energy.

Of the two remaining compounds, the radii of the ions (Li+ and F-) in LiF are smaller than the radii of the ions (K+ and Br-) in KBr.

LiF, therefore, has a stronger ionic bond , and also a **higher lattice energy than KBr**

Order of decreasing lattice energy (LE) , therefore, is:

MgO > LiF > KBr

highest LE *lowest LE*

21. **A** **Partial pressure calculation, mole fraction**

Step 1: Determine moles of the gases

40 g Ne / 20 g.mol^{-1} = 2 mol Ne

40 g He / 4 g.mol^{-1} = 10 mol He

Step 2: Determine partial pressure of Ne (P_{Ne}) using equation below.

$$P_{Ne} = \frac{\text{moles of Ne}}{\text{Total moles}} \times P_{total}$$

$$P_{Ne} = \frac{\text{2 moles Ne}}{\text{12 moles}} \times \text{6 atm}$$

P_{Ne} = 1 atm

This problem could have been solved using mental math by realizing that the mass of Ne on the Periodic Table is five times greater than that of He. That means, in a **container of equal masses of the gases,** the ratio of moles of Ne to He will always be 1 : 5, and the total moles of the gases in the container will always be 6 (or a factor of 6).

That means: The partial pressure of Ne will always be 1/6th that of the total pressure. In this problem, 1/6th of 6 atm = **1 atm**

22. **C** **Spontaneous reaction – free energy - K_{eq} relationship**

Recall: All spontaneous reactions must have – ΔG (free energy change)

Recall: In spontaneous reactions, product must be favored. Therefore:

$$K_{eq} = \frac{[\text{product}]}{[\text{reactant}]} > 1$$

Day 13: Answers and Explanations

23. **B** **Factors affecting rate of gaseous reaction**

Note: Increasing volume (condition 2) on gaseous reactions decreases the concentration of the gases (H_2 and I_2).

Relate: A decrease in concentration of reactants decreases reaction rate because the frequency of effective collision will decrease.

Note: 1 will not change rate b/c neon is a non-reactive substance

4 will not change overall rate because both forward and reverse reactions will speed up equally

3 will increase rate because kinetic energy of the particles will increase, leading to increase frequency of effective collisions

24. **C** **Charge calculation from mole of e- , factor labeling**

Recognize that moles of electrons produced from 6.54 g Zn can be determine using factor-labeling by utilizing mole proportion in the half-reaction.

$$\text{Charge} = 6.54\text{ g Zn} \times \frac{1\text{ mol Zn}}{65.4\text{ g Zn}} \times \frac{2\text{ mol e-}}{1\text{ mol Zn}} \times \frac{96500\text{ coulombs}}{1\text{ mol e-}}$$

Charge = **19300 coulombs**

If factor-labeling is not your thing: Do this problem in steps:

Step 1: Determine moles of 6.54 g of Zinc

moles = 6.54 g / 65.4 g.mol-1 = 0.100 mol Zn

Step 2: Determine moles of electrons produced from 0.100 mol Zn

1 mol Zn = 2 mol of e- (according to half-reaction)

0.100 mol Zn = 0.200 mol e-

Step 3: Calculate charge of 0.200 moles e-

Charge = 0.200 mol e- x 96500 coulomb/e-

Charge = **19300 coulombs**

Day 13: Answers and Explanations

25. **E** **Formula writing; oxidation state of atoms**

Recall: The two common oxidation states of iron are Fe^{3+} and Fe^{2+}.

Determine formulas of iron oxide with these two oxidation states.

$Fe^{3+}\ O^{2-}$ Fe_2O_3 iron (III) oxide (X)

$Fe^{2+}\ O^{2-}$ FeO iron (II) oxide (Z)

26. **E** **Molar solubility calculation; dissociation, equilibrium constant**

Recall: Molar solubility is defined as the number of moles of solutes that will dissolve in a 1 liter solution.

Recognize that based on the information given, setting up equilibrium expression and solving for moles of the ions is one way of determining molar solubility of the solute (PbI_2).

Step 1: Write the equation for the dissolving of PbI_2

$PbI_2(s)$ --------> $Pb^{2+}(aq) + 2I^-(aq)$

Step 2: Write equilibrium expression, K_{sp} , based on step 1 equation

Recall: Solids (constant [ ]) are not included in

$K_{sp} = [Pb^{2+}]\ [I\text{-}]^2$

Step 3: Assume $[Pb^{2+}] = X$

$[I\text{-}] = 2X$ (since moles of I^- is twice that of Pb^{2+})

Step 4: Substitute factors from step 3 and the K_{sp} given into equilibrium expression written in step 2. Solve for X

$K_{sp} = [Pb^{2+}]\ [I\text{-}]^2$

$3.2 \times 10^{-8} = (X)(2X)^2$

$3.2 \times 10^{-8} = 4X^3$

$\frac{3.2 \times 10^{-8}}{4} = X^3$

$8.0 \times 10^{-9} = X^3$

2.0×10^{-3} = $X = [Pb^{2+}] = [PbI_2]$ Note: mole ratio of Pb^{2+} to PbI_2 is 1 : 1

27. **E** **Rate law; Order of reaction**

Recognize that to determine the correct rate expression, the order of the reaction with respect to X and Y must be determined from information given on the Table.

Step 1: Determine order with respect Y
Compare Rates in Experiment 2 and 3 since [X] is constant.

Note: [Y] is doubled (1.5 to 3.0)
But Rate stayed the same (at 0.45)

Recall: When rate does not change, the order with respect to that reactant is 0. This means that $[Y]^0$ cannot be included in the rate law since the reaction does not depend on [Y].
Eliminate A, B and D: These choices have [Y] in their rate laws.

Step 2: Determine order with respect to X
Compare Rates in Experiment 1 and 3 since [Y] is constant.

Note: [X] is doubled (1.5 to 3.0)
Rate is 4 times greater (0.45 to 1.8)

Recall: When rate is quadrupled as [ ] is doubled, the reaction is 2nd order with respect to that reactant $[X]^2$

Step 3: Write correct rate law based on the two determinations:
Rate = $k\,[X]^2$

28. **C** **Diamagnetic – electron configuration relationship**

Recall: Diamagnetic elements have all of their subshells completed. These elements have a pair of electrons in all of their available sublevels.

Draw orbital notation for each element listed as a choice.

(A) Hydrogen $\uparrow_{1s^2}$

(B) Carbon $\uparrow\downarrow_{1s^2}$ $\uparrow\downarrow_{2s^2}$ $\uparrow_{2p^2}\uparrow$

(C) Magnesium $\uparrow\downarrow_{1s^2}$ $\uparrow\downarrow_{2s^2}$ $\uparrow\downarrow\uparrow\downarrow\uparrow\downarrow_{2p^6}$ $\uparrow\downarrow_{3s^2}$ **all sublevels completely filled (paired)**

(D) Fluorine $\uparrow\downarrow_{1s^2}$ $\uparrow\downarrow_{2s^2}$ $\uparrow\downarrow\uparrow\downarrow\uparrow_{2p^5}$

(E) Sulfur $\uparrow\downarrow_{1s^2}$ $\uparrow\downarrow_{2s^2}$ $\uparrow\downarrow\uparrow\downarrow\uparrow\downarrow_{2p^6}$ $\uparrow\downarrow_{3s^2}$ $\uparrow\downarrow\uparrow\uparrow_{3p^4}$

Day 13: Answers and Explanations

29. **C** **Buffer solution**

Recall: The best buffered solution has pKa = pH

This means that the buffered solution contains equal molar concentrations of the acid and conjugate base.

Note: Without a calculator, you must recognize that pKa for choice C will be the closest to the pH given (5)

30. **B** **Density ; Molar volume**

Recall: $\text{Density} = \dfrac{\text{Mass}}{\text{Volume}}$

Note: Molecular mass of helium (He) = 4 g

Recall: At STP, volume of a mole of gas = 22.4 L

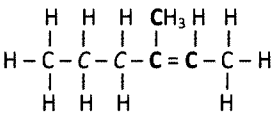
Determine: Density of He at STP = $\dfrac{4\text{ g}}{22.4\text{ L}}$

31. **A** **Hydrocarbon formula naming**

Note: You may be able to name the condensed formula given correctly without drawing out its structure.

If you choose to draw before naming, be sure the C atoms, the branch or branches, and the H atoms are all bonded correctly according to the condensed formula

$CH_3(CH_2)_2\mathbf{C}(\mathbf{C}H_3) = \mathbf{C}H\,CH_3$



Naming the structure:

Note: Methyl is on the 3rd C atom from left: 3-methyl

Note: The Long chain has 6 C atoms:
Double bond in bond position 2 : 2 - hexene

Combine names: 3-methyl , 2-hexene

32. **A** **Ideal gas law calculation**

Recognize that based on the information given, the ideal gas law equation is needed in order to calculate the number of moles (n).

Step 1: Write the ideal gas law equation

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

Step 2: Convert 77°C to Kelvin

$K = 77°C + 273 = 350\ K$

Step 3: Substitute factors into equation and solve for n

$$n = \frac{(3.0)(2.0)}{(0.0821)(350)} = \mathbf{0.21\ mol}$$

33. **D** **Antibonding definition**

Re*call:* Bonding orbitals of atoms are found in overlapping regions of the atoms, where electron density is greatest. Antibonding orbitals exist opposite these regions, which are outside the atoms.

34. **E** **Dot diagram interpretation**

Note: The Lewis electron-dot diagram has 7 dots (7 valance e-)

Infer: Element X is a halogen because all halogens have 7 valance electrons **(Eliminate Choice A)**
Halogens form – 1 charge **(Eliminate Choice B)**
Halogens have high electronegativity value **(Eliminate D)**
An Halogen can have a set of quantum numbers of 3,1,1,-½ for its valance shell. This is a quantum number set for a valance e- of a chlorine's atom, . **Eliminate C**

Note: **Choice E** is the only remaining answer. HF is a weak acid.

35. **C** **Network solid compounds, properties**

Recall: Diamond (C) is a network solid substance formed by repeated units of carbon atoms.

Recall: Network solids contain strong covalent bonding between atoms with the absence of discrete particles. This gives diamond, and other network solids such as silicon dioxide, (SiO_2) and silicon carbide (SiC)their extreme hardness.

Day 13: Answers and Explanations

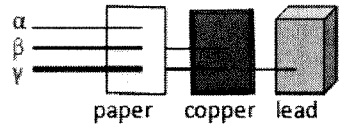
36. **D** **Penetrating power comparison, nuclear particles**

Recall: Penetrating power refers to the ability of a particle to go through another object.

Note: **αlpha particles (^4He)** have the least penetrating power because of their large mass (4)

βeta particles (^0e) encounter less resistance than alpha because their mass is much smaller.

Gamma radiations ($^0\gamma$) have the most penetrating power because they have no mass and no charge, so they encounter far less resistance than alpha and beta.



37. **D** **Adding equations**

Recognize that to calculate the value of the free energy for the reaction, equations and data from the table must be manipulated to correspond to that of the reaction.

Step 1: Note the reaction and the coefficients of the substances

$$\mathbf{6}C(s) + \mathbf{3}H_2(g) \text{ ------ > } C_6H_6(l)$$

Step 2: Manipulate each of the three equations given so that their sums is equal to the reaction above.

Equation 1: Reverse, change sign of ΔG°, and divide everything by 2

$6\ CO_2(g) + H_2O(l)$ --- > $\mathbf{C_6H_6(l)}$ + $7\frac{1}{2}\ O_2(g)$ **ΔG° = + 3200 kJ**

Equation 2: Keep equation and sign of Δ G°, multiply everything by 6

6C(s) + $6O_2(g)$ ----- > $6CO_2(g)$ **Δ G° = -2400 kJ**

Equation 3: Keep equation and sign of Δ G°, multiply everything by 3

$3H_2(g)$ + $1\frac{1}{2}\ O_2(g)$ --- > $3\ H_2O(l)$ **Δ G° = -750 kJ**

Step 3: Add the three equations and their **Δ G** values.

6C(s) + $3H_2(g)$ ------ > **$C_6H_6(l)$** **Δ G = 50. kJ**

38. **A** **Comparing Bond energy in formulas**

Recall: Bond energy increases as the number of bonds between atoms increase.

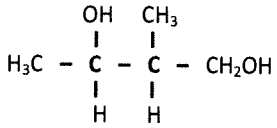
Note the number of bonds between atoms in each of the five diatomics.

N_2	O_2	Cl_2	Br_2	H_2
$N \equiv N$	$O = O$	$Cl - Cl$	$Br - Br$	$H - H$

Note: N_2, with its triple bond, has the most bonding, and therefore, highest bond energy.

39. **C** **Definition of asymmetrical Carbon**

Recall: A carbon atom of a molecule is asymmetrical if it is bonded to four different atoms or groups.



Note: Each of the **two middle C atoms** is bonded to four different atoms and groups

Note: The other 3 C's are not bonded to four different atoms & groups

40. **D** **Interpreting titration curve, relating curve to acid-base reaction**

Note the following key details about the titration curve given.

The beginning pH is very low: The acid is likely a strong acid

The end pH is very high : The base is likely a strong base

Relate: The acid is HNO_3 (strong) and the base is NaOH (strong)

41. **C** **Determining phase from phase diagram**

Note: Condensation of the gas to liquid occurs between t_2 and t_4.

Relate: At t_3, a **mixed of gas and liquid** will be present (in equal amount since t_3 is equal distance from t_2 and t_4)

Day 13: Answers and Explanations

42. **D** **Phase change , energy and entropy relationship**

Note: From time t_4 to t_5, the substance exists as a liquid, and its temperature is decreasing (kinetic energy, KE, is decreasing)

Recall: When KE is changing, **potential energy remains constant**
When KE is decreasing, particles are slowing down, **entropy decreases (- ΔS)**

43. **D** **Osmotic pressure calculation, solution property**

Recognize that based on the information given, osmotic pressure (Π) can be calculated using the equation $\Pi = iMRT$

Step 1: Determine van't Hoff factor (i) of NaCl
i for NaCl = **1** Na+ **1** Cl- = **2**

Step 2: Change 27°C temperature (T) to Kelvin
T = 27°C + 273 = 300 K

Step 3: Substitute all factors into osmotic pressure equation and solve

$\Pi = i \times M \times R \times T$

$\Pi = (2)(0.100)(0.0821)(300) =$ **4.9 atm**

44. **D** **Frequency, wavelength, and energy Relationship**

Recall the following equations that relate wavelength (λ), frequency (*v*), velocity (v), speed of light (c) and Energy (E).

$v = \lambda v$ $c = \lambda$ $E = hv$ or $E = \frac{v}{\lambda}$

Note: Based on these equations and your knowledge of electromagnetic radiation, eliminate some of the choices.

Eliminate A and E because all electromagnetic radiation travel at the same speed (velocity, v) in a vacuum. This is just a fact.

Eliminate B because according to the first equation, the higher the wavelength (λ) , the shorter the frequency (*v*) Therefore 320 nm wavelength will have a shorter frequency than a 200 nm wavelength

Eliminate C because the visible light spectrum occurs in the wavelength area of 390 to 750 nm.

Choice D is correct because according to the third equation, the higher the wavelength (λ), the lower the energy (E). Therefore, a 320 wavelength has a lower energy than a 100 nm wavelength.

45. **D** **Amphoteric species in reactions**

Recall that amphoteric is a substance that can act as an acid or a base in a reaction

Note: In equation 4, **$Al(OH)_3$** acts as **an acid** by combining with the a strong base.
In equation 5, **$Al(OH)_3$** acts as **a base** to neutralize the acid, HCl.

46. **B** **Balancing equation**

Note: The balance equation for this reaction is

$H_2SO_4 + Ca(OH)_2$ --------> $CaSO_4 + \mathbf{2}H_2O$.

47. **A** **Equilibrium constant with pressure**

Recognize that based on the choices given, the best way to answer a question like this is to eliminate choices that are clearly false based on equation and information given.

Note the equation: $2W(g)$ ---------> $2X(g) + Y(g)$,

***Eliminate* Choice C:** 2 moles of substance are producing 3 moles of substances. Therefore, entropy is increasing ($\Delta S > 0$)

***Eliminate* Choice D:** The reaction is not yet at equilibrium.
Recall: $\Delta G^\circ = 0$ only for a reaction at equilibrium

***Eliminate* Choice E:** The reaction proceed spontaneously as written. Therefore, ΔG° is negative ($G^\circ < 0$)

Note: Of the remaining choices, A is correct *because* K_p is greater than one. This is the case when reaction proceeds in the forward direction to make more products.

Recall: $\dfrac{[\text{Product}]}{[\text{Reactant}]}$

48. **E** **Relating energy to phase change**

Recall: 373 K (100°C) is the boiling point of water at standard pressure. At this temperature, energy put into the water is used for increasing potential energy of the molecules in order to overcome the intermolecular forces holding the molecules together.

49. **C** **Mole – mole calculation in equation**

Recognize that this is a mole ratio problem that is easily solved by setting up factor-labeling using correct mole proportion.

Recognize that K_2CrO_7 and C_2H_5OH will be present in excess, therefore, proportion should be set up between
HCl and CO_2 : **16** HCl ---> **2** CO_2

$$\text{moles HCl} = 4.0 \text{ mol } CO_2 \times \frac{16 \text{ mol HCl}}{2 \text{ mol } CO_2}$$

moles HCl = **32 moles**

Note: Setting up your mole proportion with any of the excess will give you a wrong calculated result for moles of HCl.

50. **A** **Interpreting redox reaction; writing equation**

Note: One way to determine all true statements about this reaction is to write the *correct equation* to represent the reaction, assign oxidation numbers to species in the reaction, and note oxidation number changes of the substances

Step 1: Write correct equation to represent reaction described.

FeS + O_2 ------> FeO + SO_2

Step 2: Assign correct oxidation numbers to substances

+2 ***-2*** **0** +2 *-2* ***+4*** -2
Fe ***S*** + ***O_2*** ------> Fe **O** + ***S O_2***

Step 3: Note and interpret changes in oxidation numbers

S^{2-} ---> S^{4+} ***Sulfur*** is oxidized, also the ***reducing agent*** (because its oxidation number increases)

O_2^{0} ---> O^{2-} **Oxygen** is reduced , also the **oxidizing agent** (because its oxidation number decreases)

Day 14: Answers and Scoring Guidelines

(see important scoring guideline information on on pg i)

1. The solubility of $Mg(OH)_2$, magnesium hydroxide, is 6.53×10^{-3} g/L at 25°C. Assume that this temperature is maintained for all parts of the question. **(10 points)**

(a) Write a balanced equation for the solubility equilibrium.

$Mg(OH)_2\,(s) <====> Mg^{2+}\,(aq) + 2OH^-(aq)$	**1 point** for the correct and a balanced equation

(b) Based on the equilibrium expression you wrote:

(i) Write expression for the K_{sp}

Recall: K_{sp} = [Products]

Note: Solids are not included in equilibrium expression of any kind because of their constant concentration

$K_{sp} = [Mg^{2+}]\,[OH^-]^2$	**1 point** for the correct expression

(ii) Determine the K_{sp} value from the expression in (b).

Note: In order to calculate K_{sp} value, $[Mg^{2+}]$ and [OH-] must be determined.

Determine the molar solubility (M) of $Mg(OH)_2$ based on information given:

M = solubility x molar mass of solute

$$M = \frac{6.53 \times 10^{-3}\ g}{L} \times \frac{1\ mol}{58\ g}$$

M = 1.12 x 10^{-4} M

1 point is earned for calculating molar solubility of Mg(OH)2

Determine concentration of substances

Let X = molar solubility M of $Mg(OH)^2$
X = $[Mg^{2+}]$ because they are at 1 : 1 ratio
2X = [OH-] because they are at 2 : 1 ratio

Re-write K_{sp} expression, substituting X's for [ ]'s, and solve for K_{sp}

$K_{sp} = [Mg^{2+}]\ [OH\text{-}]^2$

$K_{sp} = (X)\ (2x)^2$

$K_{sp} = 4X^3$

$K_{sp} = 4\ (1.12 \times 10^{-4}\ M)^3$

K_{sp} = 5.62 x 10^{-12}

1 point is earned for setup to calculate K_{sp}

1 point is earned for the correct K_{sp} value

Day 14: Answers and Scoring Guidelines

(c) Calculate the pH of a saturated solution of $Mg(OH)_2$.

Note: The quickest way to solve this problem is to determine the pOH of the solution based on previously calculated values.

Determine the [OH-] in the solution

[OH-] = 2 X = 2(1.12 x 10^{-4} M) = 2.24 x 10^{-4} M

Determine pOH

pOH = -log [OH-]
pOH = -log (2.24 x 10^{-4} M) = 3.6

Determine pH

pH = 14 – pOH
pH = 14 – 3.6 = 10.4

1 point is earned for the correct pH value

(d) If 100 mL of 2.5 x 10^{-3} M $Mg(NO_3)_2$ solution is added to 100 mL of a 3.5 x 10^{-4} M NaOH solution:

(i) What will be the concentration of the magnesium and hydroxide ions in the solution?

Determine $[Mg^{2+}]$ in the $Mg(NO_3)_2$ solution

mole Mg^{2+} = Volume $Mg(NO_3)_2$ x Molality $Mg(NO_3)_2$

mole Mg^{2+} = .100 L x 2.5 x 10^{-3} mol/L

mole Mg^{2+} = 2.5 x 10^{-4} moles

$$[Mg^{2+}] = \frac{\text{mol } Mg^{2+}}{\text{total Volume}} = \frac{2.5 \times 10^{-4}\ \text{mol}}{.200\ L} = \mathbf{1.25 \times 10^{-3}\ M}$$

1 point is earned for the correctly calculating $[Mg^{2+}]$

Determine [OH-] in the NaOH solution

mole OH- = Volume NaOH x Molality NaOH

mole OH- = .100 L x 3.5 x 10^{-4} mol/L

mole OH- = 3.5 x 10^{-5} moles

$$[OH\text{-}] = \frac{\text{mole OH-}}{\text{total volume}} = \frac{3.5 \times 10^{-5}\ \text{mol}}{.200\ L} = \mathbf{1.75 \times 10^{-4}\ M}$$

1 point is earned for the correctly calculating [OH-]

(ii) Will a precipitate of $Mg(OH)_2$ formed in the solution?
Justify your response by using your calculated data.

Recall: For precipitate to form in a solution, the reaction quotient (Q) must be greater than K_{sp}: Q > Ksp

Determine Q using the calculated concentrations: $Q = [Mg^{2+}][OH^-]^2$ $Q = (1.25 \times 10^{-3}\ M)(1.75 \times 10^{-4}\ M)^2$ **$Q = 3.8 \times 10^{-11}$** *Note:* $Q > K_{sp}$ $3.8 \times 10^{-11} > 5.62 \times 10^{-12}$ **Precipitate of $Mg(OH)_2$ will form** because **$Q > K_{sp}$** *Note:* Precipitate is formed as a means of removing excess $Mg(OH)_2$ from solution and restore equilibrium.	**1 point** is earned for correctly calculating Q **1 point** is earned for indicating precipitate of $Mg(OH)_2$ with correct comparison of Q to Ksp

Day 14: Answers and Scoring Guidelines

2. **(10 points)**

Energy is released when glucose is oxidized in the following reaction, which is a metabolism reaction that takes place in the body.

$$C_6H_{12}O_6(s) + 6O_2(g) \text{ ------> } 6CO_2(g) + 6H_2O(l)$$

The standard enthalpy change, ΔH°, for the reaction is - 2,801 KJ at 298 K.

(a) Calculate the standard entropy change , ΔS°, for the oxidation of glucose.

Recall: $\Delta S^\circ = \sum S^\circ products - \sum S^\circ reactants$

Substitute data from table into equation. *Be sure to take all coefficients into account.* $\Delta S^\circ = \sum S^\circ_{products} - \sum S^\circ_{reactants}$ $\Delta S^\circ = [(6)(213) + (6)(70.0)] - [(212) + (6)(205)]$ **$\Delta S^\circ = 255$ J/K**	**1 point** is earned for correctly calculating the ΔS°

(b) Calculate the standard free energy change, ΔG°, for the reaction at 298K.

Note: $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ (see Reference Materials)

Convert the calculated ΔS° to KJ (because ΔH is in KJ) 255 J/K = 0 .255 KJ/K *Substitute factors into equation and solve* $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ **ΔG° = -2801 KJ – (298 K) (0.255 KJ/K)** **ΔG° = -2880 KJ**	**1 point** is earned for setup **1 point** is earned for correctly calculating the ΔG°

Day 14: Answers and Scoring Guidelines

(c) At which temperature, if any, would the spontaneity of this reaction change. Justify your answer with an explanation.

Note: The reaction is spontaneous because its G° value is negative (-)

Note: Spontaneity can change:

If ΔG° changes to Zero: The reaction will be at equilibrium.

If ΔG° changes to positive: The reaction will become nonspontaneous.

The question is at which temperature would ΔG become zero or +

Note: The reaction in this question has $-\Delta H$ and $+\Delta S$

Spontaneity will not change at any temperature. **Reaction will always be spontaneous at any temperature.** Since $\Delta G^\circ = -\Delta H^\circ - T\Delta S^\circ$ for this reaction, ΔG° will always be negative (reaction will always be spontaneous) because **at any temperature , $T\Delta S$ value will always be positive.**	**1 point** is earned for indicating no change **1 point** is earned for the correct justification

(d) What is the value K_{eq} for the reaction?

Note : $\Delta G^\circ = -2.303\ RT \log K_{eq}$ (See Reference Materials)

$\log K_{eq} = \dfrac{G^\circ}{-2.303\ RT}$	**Note:** ΔG value is converted to J because R (the gas constant) is in Joules.	
$\log K_{eq} = \dfrac{\mathbf{-2\ 880\ 000}}{\mathbf{(-2.303)\ (8.31)(298)}}$		**1 point** is earned for setup.
$\log K_{eq} = 505$		**1 point** is earned for correctly calculating the K_{eq}
$\mathbf{K_{eq} = 10^{505}}$		

Day 14: Answers and Scoring Guidelines

(e) How much energy is given off by the oxidation of 1.0 grams of glucose?

Note: ΔH° , the enthalpy change of the reaction, given in the problem (-2801 KJ) is the amount of energy given off by oxidation of 1 mole (180 g) of glucose.

Recognize that in this question, you are calculating ΔH° given off by just 1.0 g of glucose.

Determine moles of glucose ($C_6H_{12}O_6$) $1\ g\ C_6H_{12}O_6 \times \dfrac{1\ mole}{180\ g} = \mathbf{0.00556\ moles}$ *Calculate ΔH° for 1 g based on mole to ΔH ratio in the balanced equation* $0.00556\ mol\ C_6H_{12}O_6 \times \dfrac{-2801\ KJ}{1\ mol\ C_6H_{12}O_6} = \mathbf{-15.6\ KJ}$	**1 point** is earned for calculating moles of glucose **1 point** is earned for correctly calculating the ΔH° value

(f) A student conducted a laboratory experiment to determine the standard enthalpy change, ΔH°, for oxidation of glucose. From his data, the student calculated a result that was 11.3 % below the accepted value of ΔH for glucose. What was the value of the standard enthalpy change from the student's experiment? Assume the experiment was conducted at 298 K.

Note: The accepted ΔH° value glucose = - 2,801 KJ (given in question)

Student error = (0.113) (- 2,801 KJ) = - 316.5 KJ **Student ΔH° value** = - 2,801 KJ - (-316.5KJ) = **-2484.5 KJ**	**1 point** is earned for the correct ΔH° value

Day 15 Question 2: Space for Work and Answers

Day 15: Answers and Scoring Guidelines

(see important scoring guideline information on on pg i)

1. **(15 points)**

(a) Solid sodium hydride is added to water

Recall: Metal hydrides combine with water to produce bases and hydrogen gas.

Note: The base formed (sodium hydroxide) must be in ionized form because strong bases ionize completely.

(i) Balanced equation **NaH + H_2O -----> Na^+ + OH^- + H_2** *metal hydride* *water* *base* *hydrogen gas*	**1 point** is earned for correct reactants **2 points are** earned for correct products **1 point** is earned for correctly balancing the atoms and charge

(ii) If 10 grams of sodium hydride react, how many milliliters of the gaseous product will form?

Determine moles of the gas, H_2, produced $10\text{ g NaH} \times \frac{1\text{ mole NaH}}{24\text{ g NaH}} \times \frac{1\text{ mole } H_2}{1\text{ mole NaH}} = 0.416\text{ mol } H_2$ *Calculate volume of H_2 at STP* $0.416\text{ mol } H_2 \times \frac{22.4\text{ L}}{1\text{ mol}} \times \frac{1000\text{ mL}}{1\text{ L}} = \mathbf{9318\text{ mL } H_2}$	**1 point** is earned for correctly calculating the volume of H_2.

(b) A solution of hydrogen peroxide is heated.

Note: This is a decomposition reaction of hydrogen peroxide to water and oxygen.

(i) Balanced equation $2H_2O_2$ ---------> $2H_2O + O_2$	**1 point** is earned for correct reactants **2 points are** earned for correct products **1 point** is earned for correctly balancing the equation

(ii) Indicate all oxidation numbers of oxygen before and after the reaction.

Recall: Oxygen has a -1 charge in peroxides.
+2 charge in OF_2
-2 charge in all other compounds

-1 before reaction (in H_2O_2) **-2 after reaction** (in H_2O) **0 after reaction** (in O_2)	**1 point** is earned for correctly listing all oxidation numbers of O

Day 15: Answers and Scoring Guidelines

(c) A copper coil is placed in a silver nitrate solution.

Note: This is a single replacement reaction in which silver ion is reduced to silver metal.

NO_3^- ion is unchanged, therefore, not included in the equation.

(i) Balanced equation **Cu + 2Ag+ --------> Cu^{2+} + 2Ag**	**1 point** is earned for correct reactants **2 points are** earned for correct products **1 point** is earned for correctly balancing the atoms and charge

(ii) Indicate any visible change that would occur in the reaction container as the reaction is proceeding.

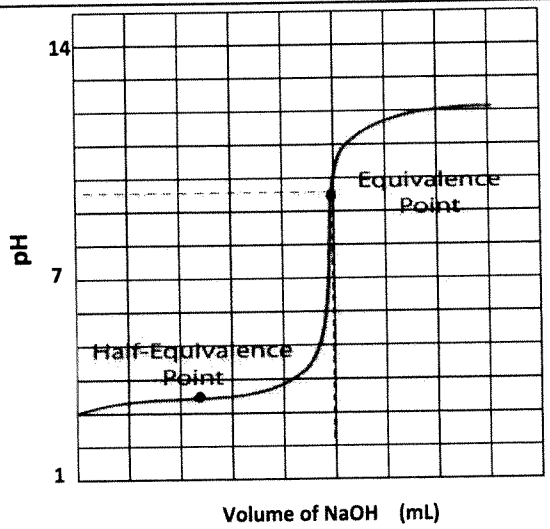
Grayish solid silver will form on the copper coil. **The solution will turn blue as copper ion is formed in the solution.**	**1 point** for listing any change that is typical for this reaction

Day 15: Answers and Scoring Guidelines

2. **(8 points)**

A student performed a titration of a weak monoprotic acid, HA , with a sodium hydroxide, NaOH, solution.

(a) On the graph below, sketch an appropriate representation of the titration curve for the experiment. On the curve, label the half-equivalent point and the equivalent point.



Your diagram will vary a bit from the one above. Points are based on the followings:

The curve starts at pH between 3 to 5 and levels off at the end before 14	**1 point** is earned for a correctly drawn curve
The half-equivalence point is labeled at appropriate point at the beginning of the curve.	**1 point** is earned for correct half-equivalence point
The equivalence point is labeled at a pH between 8 and 12.	**1 point** is earned for correct equivalence point

Day 15: Answers and Scoring Guidelines

(b) Discuss at least two ways in which a sketch from the titration of a strong, monoprotic, like HCl will differ from the your sketch in (a)

Note: The curve for the weak acid has equivalent point at a pH that is much higher than 7. **One: A curve for a strong acid like HCl have equivalent point pH right around 7.**	**1 point** is earned for correctly discussing ph around equivalent point
Note: The steepness of the curve around the equivalent point for the weak acid is very short and shows a very small increase in pH due to the high starting pH of the weak acid. **Two: The steepness of a curve around the equivalent point for a strong acid like HCl will be much larger and will show a large increase in pH** due to the low starting pH of a strong acid.	**1 point** is earned for correctly discussing steepness around equivalent point

(c) The student has a choice between the two indicators: methyl red (pH range = 4.8 – 6.0) or phenolphthalein (pH range = 8.2 – 10.0). Which should she choose? Justify your response.

Phenolphthalein Since this is a titration of a weak acid by a strong base, **the equivalent point will be at a pH greater than 7 and the change in pH is gradual**. An indicator that changes color at or above pH 7 will be a good indicator for this titration. Phenolphthalein changes color at a pH range of 8 – 10.	**1 point** is earned for mentioning Phenolphthalein **1 point** is earned for correct justification of indicator that is mentioned

Day 15: Answers and Scoring Guidelines

(d) Assume that the acid in this titration was acetic acid, what will be the formula and name of the product (other than water) that is formed during the titration process?

Note the balanced equation for the reaction that will occur during the titration process

$$HC_2H_3O_2 + NaOH \text{ -------> } H_2O + NaC_2H_3O_2$$

acetic acid — *sodium hydroxide* — *water* — *sodium acetate*

$NaC_2H_3O_2$ **Sodium acetate**	**1 point** is earned for the correct formula and name.

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.

   $$\underset{\textit{alkaline earth}}{Be} + \underset{\textit{water}}{H_2O} \text{ -----> } \underset{\textit{base}}{Be(OH)_2} + H_2$$

Day 16: Answers and Explanations.

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

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

Day 16: Answers and Explanations.

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**	**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: $Zn \text{ -------} > Zn^{2+} + 2e^-$

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

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

Day 16: Answers and Explanations.

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*

Day 16: Answers and Explanations.

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.

Day 16: Answers and Explanations.

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.

$\overset{+2\ -3}{8C\,N^-} + \overset{0}{4Ag} + \overset{0}{O_2} + \overset{+1\ -2}{2H_2O}$ ------ > $\overset{+1\ +2\ -3}{4Ag(CN)_2^-} + \overset{-2\ +1}{4\,OH^-}$

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

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

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

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

Day 16: Answers and Explanations.

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

$$H_2O(l) \text{ -------> } H_2O(s)$$

Note: The change shown is freezing:

ΔH is – (exothermic) because heat is released as liquid freezes: **ΔH < 0**

ΔS is – (↓ entropy) because particles become more organized: **ΔS < 0**

Δ V is + (↑ volume) because water expands as it turns to ice: **ΔV > 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-

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

(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 $VP_{toluene\ (60)}$

Day 16: Answers and Explanations.

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.

Day 16: Answers and Explanations

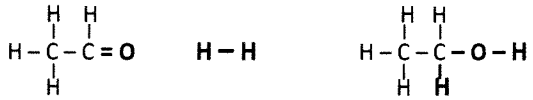
43. **C** **Hess Law, bond energy**

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

$\Delta H^\circ = \sum \Delta H^\circ Reactants + \sum \Delta H^\circ products$

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

$CH_3CHO + H_2 \text{ ----------> } CH_3CH_2OH$



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

$\Delta H^\circ = \sum \Delta H^\circ Reactants + \sum \Delta H^\circ products$

$-71 = X + 435 + -1229$

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

Day 16: Answers and Explanations

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

Day 16: Answers and Explanations

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)*

Day 16: Answers and Explanations.

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 **$2Cu + O_2 + 4H^+ \rightarrow 2Cu^{2+} + 2H_2O$**

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

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

$E^\circ = -0.34\text{ V} + 1.23\text{ V} = +\mathbf{0.89\text{ V}}$

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

$\Delta G^\circ = -n F E^\circ$

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)

$\Delta G^\circ = -n F E^\circ$

$\Delta G^\circ = -4(96{,}500\text{ J/V}^{-1}\text{mol}^{-1})(0.89\text{ V})$

$\Delta G^\circ = -343{,}500$ J/mol $\approx$ **-340 KJ/mol**

Day 17: Answers and Scoring Guidelines

(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: $K_a = \dfrac{[\text{Products}]}{[\text{Reactants}]}$

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

$K_a = \dfrac{\mathbf{[C_6H_5COO^-][H_3O^+]}}{\mathbf{[C_6H_5COO]}}$	**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

$[C_6H_5COO^-] = X$

$[H_3O^+] = X$

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

$[C_6H_5COO^-] = 0.010\ M - X \approx 0.010M$ (low dissociation)

1 point is earned for substituting concentration into Ka equation

Substitute factors into K_a expression and solve for X

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

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

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

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

1 point is earned for correctly calculating the $[C_6H_5COO^-]$

Day 17: Answers and Scoring Guidelines

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

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

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

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

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

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

$[OH-] = \dfrac{1.0 \times 10^{-14}}{[H+]} = \dfrac{1.0 \times 10^{-14}}{5.5 \times 10^{-6}\ M}$ **$[OH-] = 1.82 \times 10^{-9}$ 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.

$2\ C_6H_5COOH + Ca(OH) \text{ ----> } H_2O + Ca(C_6H_5COO)_2$ *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

Day 17: Answers and Scoring Guidelines

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 x 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:

$A = abc$

$c = \frac{A}{ab}$ $c = \frac{1.20}{(5.0 \times 10^3\ cm^{-1}M^{-1})(1.00\ cm)}$ **$c = 2.4 \times 10^{-4}$ 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
$\ln (.333) = -k\,(25\ min)$ $-1.10 = -k\,(25\ min)$ **$4.4 \times 10^{-2}\ min^{-1} = k$**	**1 point** for calculating the rate constant with the correct unit.

(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.

$\ln \frac{[Z]_t}{[Z]_o} = -kt$ $\ln \frac{[3.0 \times 10^{-5}]}{[2.4 \times 10^{-4}]} = -(4.4 \times 10^{-2})(t)$ $\ln (.125) = -(4.4 \times 10^{-2})(t)$ $-2.08 = -(4.4 \times 10^{-2})(t)$ **47.2 min = t**	**1 point** for setup **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:

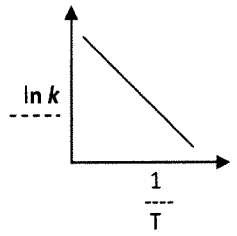
$$t_{1/2} = \frac{\ln(1/2)}{k}$$ (see reference material pg

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

Day 17: Answers and Scoring Guidelines

(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.

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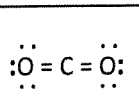
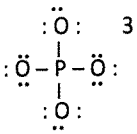
2) 2. Answer each of the following questions about CO_2 and PO_4^{3-} ion **(8 point)**

(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 **Lewis acid: CO_2** The **C** accepts the pair of electrons from O	**1 point** for correct Lewis base **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