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) $(\text{velocity})^2$
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

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)

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

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

Step 1: Determine factors from questions
$\Delta E = ?$ $\Delta H = 505.64$ J
$P = 2$ atm $\Delta V = 6L - 5L = 1L$

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

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

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

$P_A = P_A{}^o X_A$
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

H – Cl (with 3 lone pairs on Cl) **There are 3 lone pairs (nonbonding pair) of electrons**

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

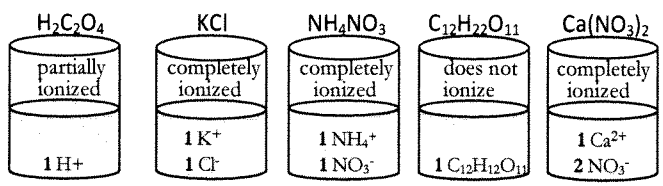
$MgO(s) + H_2(g)$ ----> $Mg(s) + H_2O(g)$ $\Delta H = -14.0$ kilojoules

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:

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

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

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

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

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

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

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

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

Step 2: Determine fraction remaining using equation

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

Step 3: Change fraction to percent

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

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 **e**ach 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

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 x 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 x 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 ($Rate_i$) .

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

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

Write dissociation equation HCOOH <===> H+ + HCOO- *Write equilibrium expression from your equation* $K_a = \frac{[\text{products}]}{[\text{reactants}]} = \frac{[H^+][HCOO^-]}{[HCOOH]}$	**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 x 10^{-3} M = [H+]**	**1 point** is earned for calculating [H+] or [OH-]
Determine [OH-] **[OH-]** $= \frac{kw}{[H+]} = \frac{1.0 \times 10^{-14}}{6.7 \times 10^{-3}}$ = **1.49 x 10^{-12} 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)

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

Note: [HCOO-] = [H+] = 6.7 x 10^{-3} M % dissociation $= \frac{[HCOO-]}{[HCOOH] + [HCOO-]} \times 100$ % dissociation $= \frac{\mathbf{6.7 \times 10^{-3}}}{\mathbf{0.25 + (6.7 \times 10^{-3})}}$ **x 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 x 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**	**1 point** is earned for calculating initial concentrations of formic and 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) *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.

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

Day 2: Answers and Scoring Guidelines

(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
$\mathbf{[Mg^{2+}] = 0.120 \text{ M}}$	**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 $Sn + \mathbf{2}Cl_2$ ------> $SnCl_4$	**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 $\mathbf{2}C_2H_6 + \mathbf{7}O_2$ -------> $\mathbf{4}CO_2 + \mathbf{6}H_2O$	**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: $Zn + \mathbf{2}H^+$ -------> $H_2 + Zn^{2+}$	**1 point** is earned for correct reactants **2 points** are earned for correct products **1 point** is earned for correctly balancing the equation

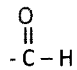
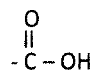
(ii) Indicate two observable changes that will be noted as the reaction proceeds in the test tube.

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.

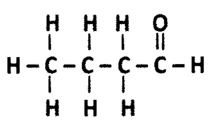
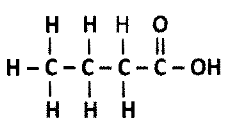
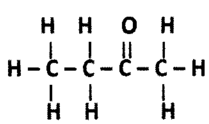
Day 3: Answers and Scoring Guidelines

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

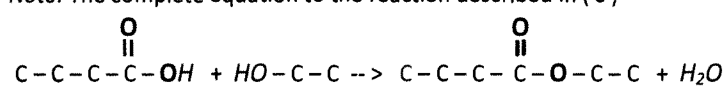
(c) Ethanol is added to each of the three vials. With which of the three compounds is ethanol most likely to react to produce an ester?

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

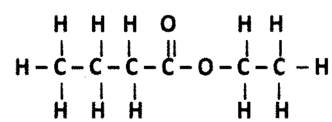
Organic acid	**1 point** is earned for correctly identifying organic acid

(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 *(butanoic)* — *alcohol* *(ethanol)* — *ester* *(ethyl butanoate)* — *water*

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