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:* *Amorphous 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**

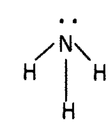
Note: This is a double replacement (ion-exchange) reaction.

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.

$$P_{Ne} = \frac{\text{moles of Ne}}{\text{Total moles}} \times P_{total}$$

$$P_{Ne} = \frac{\text{2 moles Ne}}{\text{12 moles}} \times \text{6 atm}$$

$\mathbf{P_{Ne} = 1\ atm}$

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:

$$K_{eq} = \frac{[\text{product}]}{[\text{reactant}]} > 1$$

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

$K_{sp} = [Pb^{2+}]\,[I^-]^2$

Step 3: Assume $[Pb^{2+}] = X$

$[I^-] = 2X$ (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

$K_{sp} = [Pb^{2+}]\,[I^-]^2$

$3.2 \times 10^{-8} = (X)(2X)^2$

$3.2 \times 10^{-8} = 4X^3$

$\frac{3.2 \times 10^{-8}}{4} = X^3$

$8.0 \times 10^{-9} = X^3$

$\mathbf{2.0 \times 10^{-3}} = X = [Pb^{2+}] = [PbI_2]$ 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	↑ $1s^2$					
(B) Carbon	↑↓ $1s^2$	↑↓ $2s^2$	↑ ↑ $2p^2$			
(C) Magnesium	↑↓ $1s^2$	↑↓ $2s^2$	↑↓ ↑↓ ↑↓ $2p^6$	↑↓ $3s^2$		**all sublevels completely filled (paired)**
(D) Fluorine	↑↓ $1s^2$	↑↓ $2s^2$	↑↓ ↑↓ ↑ $2p^5$			
(E) Sulfur	↑↓ $1s^2$	↑↓ $2s^2$	↑↓ ↑↓ ↑↓ $2p^6$	↑↓ $3s^2$	↑↓ ↑ ↑ $3p^4$	

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

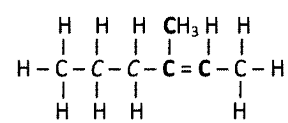
Determine: Density of He at STP $= \dfrac{4\text{ g}}{22.4\text{ L}}$

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

$CH_3(CH_2)_2\mathbf{C}(CH_3) = \mathbf{CH}\,CH_3$



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**

Recall: 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.

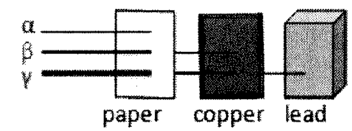
36. **D** **Penetrating power comparison, nuclear particles**

Recall: Penetrating power refers to the ability of a particle to go through another object.

Note: **αlpha particles (^{4}He)** have the least penetrating power because of their large mass (4)

βeta particles (^{0}e) encounter less resistance than alpha because their mass is much smaller.

Gamma radiations (^{0}γ) 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

6C(s) + **3**H_2(g) ------> 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) ---> **C_6H_6(l)** + 7 ½ 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 ½ 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.

```
        OH   CH3
        |    |
H3C  -  C  - C  -  CH2OH
        |    |
        H    H
```

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)

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 Π = 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 (υ), speed of light (c) and Energy (E).

$\upsilon = \lambda v$ c = λ E = hv or $E = \frac{\upsilon}{\lambda}$

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, υ) 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 + $Ca(OH)_2$ --------> $CaSO_4$ + **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: $\frac{[Product]}{[Reactant]}$

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

$$\overset{+2}{Fe}\overset{-2}{\boldsymbol{S}} + \overset{0}{\boldsymbol{O_2}} \text{ ------> } \overset{+2}{Fe}\overset{-2}{\boldsymbol{O}} + \overset{+4}{\boldsymbol{S}}\overset{-2}{\boldsymbol{O_2}}$$

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 x 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} = $[Mg^{2+}]\ [OH^-]^2$ K_{sp} = $(X)\ (2x)^2$ K_{sp} = $4X^3$	**1 point** is earned for setup to calculate K_{sp}
K_{sp} = $4\,(1.12 \times 10^{-4}\ M)^3$ **K_{sp} = 5.62 x 10^{-12}**	**1 point** is earned for the correct K_{sp} value

(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 $[Mg^{2+}] = \frac{mol\ Mg^{2+}}{total\ Volume} = \frac{2.5 \times 10^{-4}\ mol}{.200\ L}$ = **1.25 x 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 $[OH^-] = \frac{mole\ OH^-}{total\ volume} = \frac{3.5 \times 10^{-5}\ mol}{.200\ L}$ = **1.75 x 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:* $Q > K_{sp}$ $3.8 \times 10^{-11} > 5.62 \times 10^{-12}$	**1 point** is earned for correctly calculating Q
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 indicating precipitate of $Mg(OH)_2$ with correct comparison of Q to Ksp

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.

$$C_6H_{12}O_6(s) + 6O_2(g) \longrightarrow 6CO_2(g) + 6H_2O(l)$$

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*	**1 point** is earned for setup
$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ **$\Delta G^\circ = -2801\ KJ - (298\ K)(0.255\ KJ/K)$** **$\Delta G^\circ = -2880\ KJ$**	**1 point** is earned for correctly calculating the ΔG°

(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.**	**1 point** is earned for indicating no change
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 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)

$$\log K_{eq} = \frac{G^\circ}{-2.303\ RT}$$

Note: ΔG value is converted to J because R (the gas constant) is in Joules.

$$\mathbf{\log K_{eq} = \frac{-2\,880\,000}{(-2.303)(8.31)(298)}}$$

1 point is earned for setup.

$$\log K_{eq} = 505$$

$$\mathbf{K_{eq} = 10^{505}}$$

1 point is earned for correctly calculating the K_{eq}

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(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 ($C_6H_{12}O_6$) $1\text{ g } C_6H_{12}O_6 \times \frac{1\text{ mole}}{180\text{ g}} = \mathbf{0.00556\ moles}$	**1 point** is earned for calculating moles of glucose
Calculate ΔH° for 1 g based on mole to ΔH ratio in the balanced equation $0.00556\text{ mol } C_6H_{12}O_6 \times \frac{-2801\text{ KJ}}{1\text{ mol } C_6H_{12}O_6} = \mathbf{-15.6\ KJ}$	**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* (NaH), *water* (H_2O), *base* (OH^-), *hydrogen gas* (H_2)	**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.

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(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

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(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

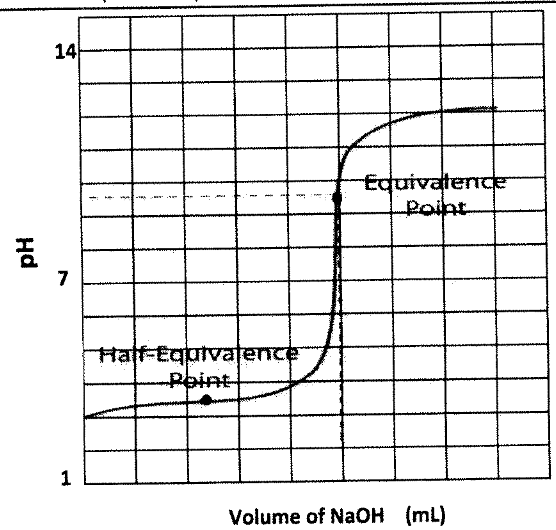
(ii) Indicate any visible change that would occur in the reaction container as the reaction is proceeding.

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

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

(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	**1 point** is earned for mentioning 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 correct justification of indicator that is mentioned

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(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

$$HC_2H_3O_2 + NaOH \dashrightarrow H_2O + NaC_2H_3O_2$$

$HC_2H_3O_2$	$NaOH$	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.