**Unit 1a**

A student is given the task of determining the molar concentration of a CuSO4 solution using two different procedures, precipitation and spectrophotometry. For the precipitation experiment, the student adds 20.0 mL of 0.200 M Ba(NO3)2 to 50.0 mL of the CuSO4 (aq). The reaction goes to completion, and a white precipitate forms. The student filters the precipitate and dries it overnight. The data are given in the following table.

Mass of dry filter paper 0.764 g Volume of 0.200 M Ba(NO3)2 20.0 mL

Volume of CuSO4(aq) 50.0 mL Mass of filter paper and dried precipitate 1.136 g

1. Write a balanced net ionic equation for the precipitation reaction.
2. Calculate the number of moles of precipitate formed.
3. Calculate the molarity of the original CuSO4 solution.

For the spectrophotometry experiment, the student first makes a standard curve. The student uses a 0.1000 M solution of CuSO4(aq) to make three more solutions of known concentration (0.0500 M, 0.0300 M, and 0.0100 M) in 50.00 mL volumetric flasks.

1. Calculate the volume of 0.1000 M CuSO4(aq) needed to make 50.00 mL of 0.0500 M CuSO4(aq).
2. Briefly list the steps necessary to prepare 50.00 mL of 0.0500 M CuSO4(aq) using only the equipment selected from the choices given. Assume that all appropriate safety measures are already in place. Not all equipment or lines in the table may be needed.

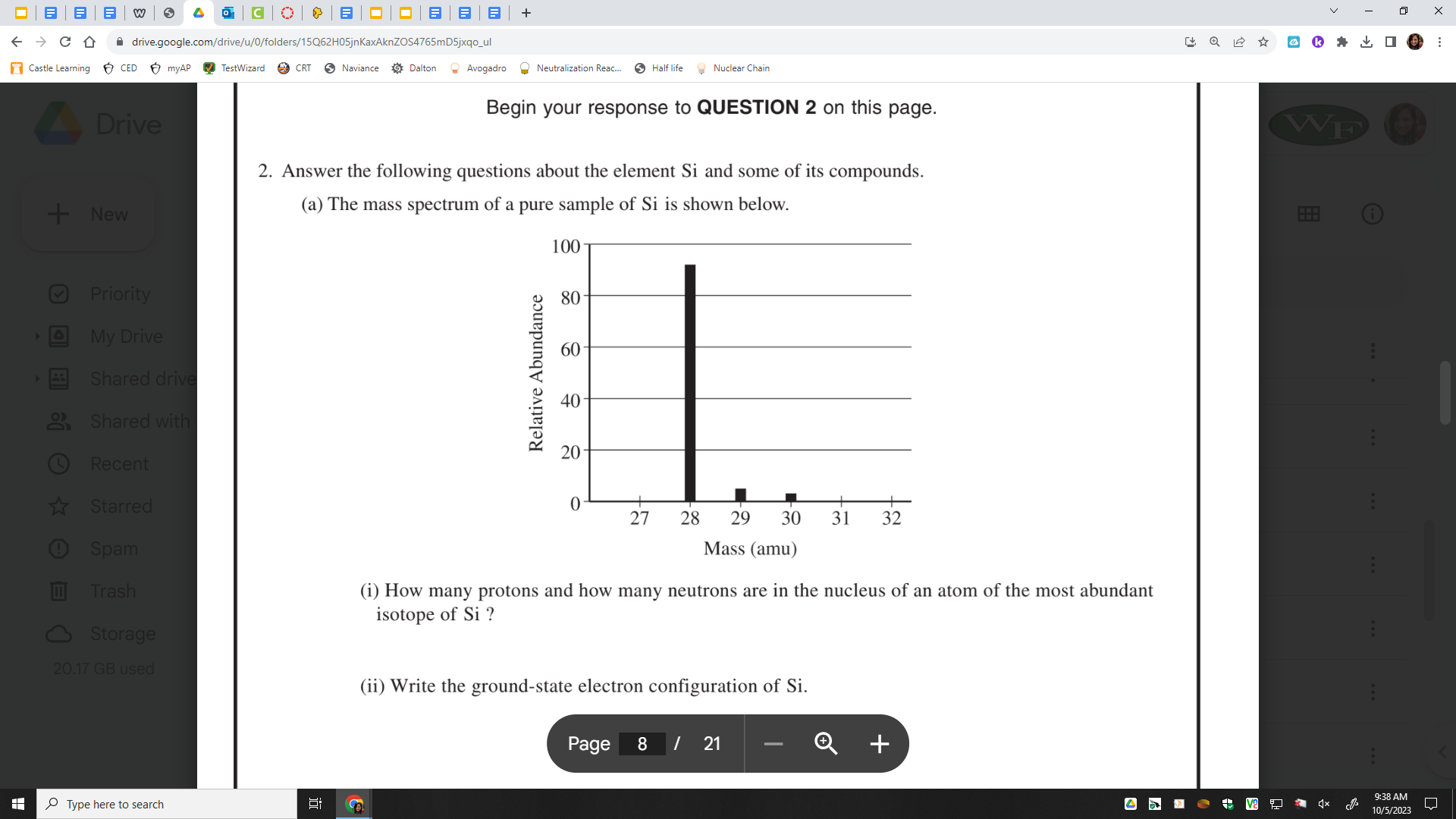
* 0.1000 M CuSO4(aq)
* 50.00 mL volumetric flask
* Distilled water
* Weigh boat
* 50.00mL beaker
* Balance
* Stirring rod
* Graduated cylinder

| Step | Step Description |
| --- | --- |
| 1. |  |
| 2. |  |
| 3. |  |
| 4. |  |

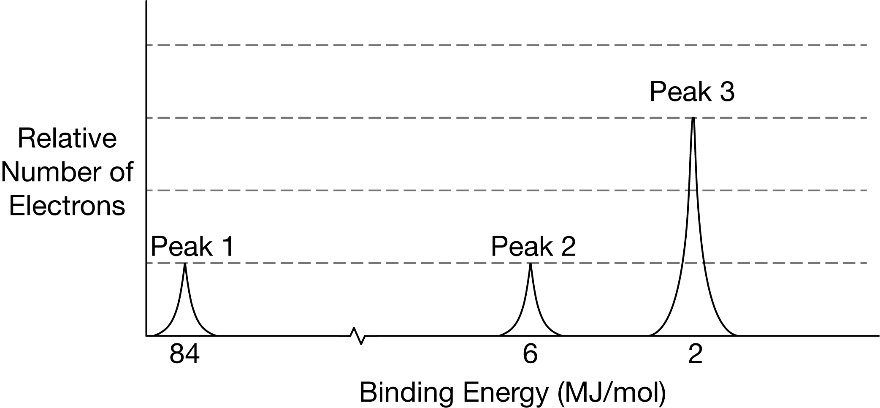
**Unit 1 b**

Answer the following questions about the element Si and some of its compounds.

* 1. The mass spectrum of a pure sample of Si is shown below.



* 1. How many protons and how many neutrons are in the nucleus of an atom of the most abundant isotope of Si ?
  2. Write the ground-state electron configuration of Si.



2. The complete photoelectron spectrum of a pure element is shown in the diagram above. According to the complete photoelectron spectrum, which of the following is the identity of the element?

(A) Be (B) C (C) O (D) Ne

3. The complete photoelectron spectrum of a pure element is shown in the diagram above. If peaks 1 and 2 represent *s* sublevels, which of the following sublevels is represented by peak 3?

(A) *s* (B) *p* (C) *d* (D) *f*

|  | Ionization Energies  (kJ/mol) |
| --- | --- |
| First | 590 |
| Second | 1150 |
| Third | 4910 |
| Fourth | 6490 |

4. Based on the ionization energies of element X given in the table above, which of the following is most likely the formula of the compound formed between element X and SO42– ?

(A) XSO4 (B) X2SO4 (C) X2(SO4)3 (D) X(SO4)2

X(*g*) → X+(*g*) + *e*– IE1 = 740 kJ/mol

X+(*g*) → X2+(*g*) + *e*– IE1 = 1450 kJ/mol

X2+(*g*) → X3+(*g*) + *e*– IE1 = 7730 kJ/mol

5. For element X represented above, which of the following is the most likely explanation for the large difference between the second and third ionization energies?

1. The effective nuclear charge decreases with successive ionizations.
2. The shielding of outer electrons increases with successive ionizations.

(C) The electron removed during the third ionization is, on average, much closer to the nucleus than

the first two electrons removed were.

(D) The ionic radius increases with successive ionizations.

Unit 2

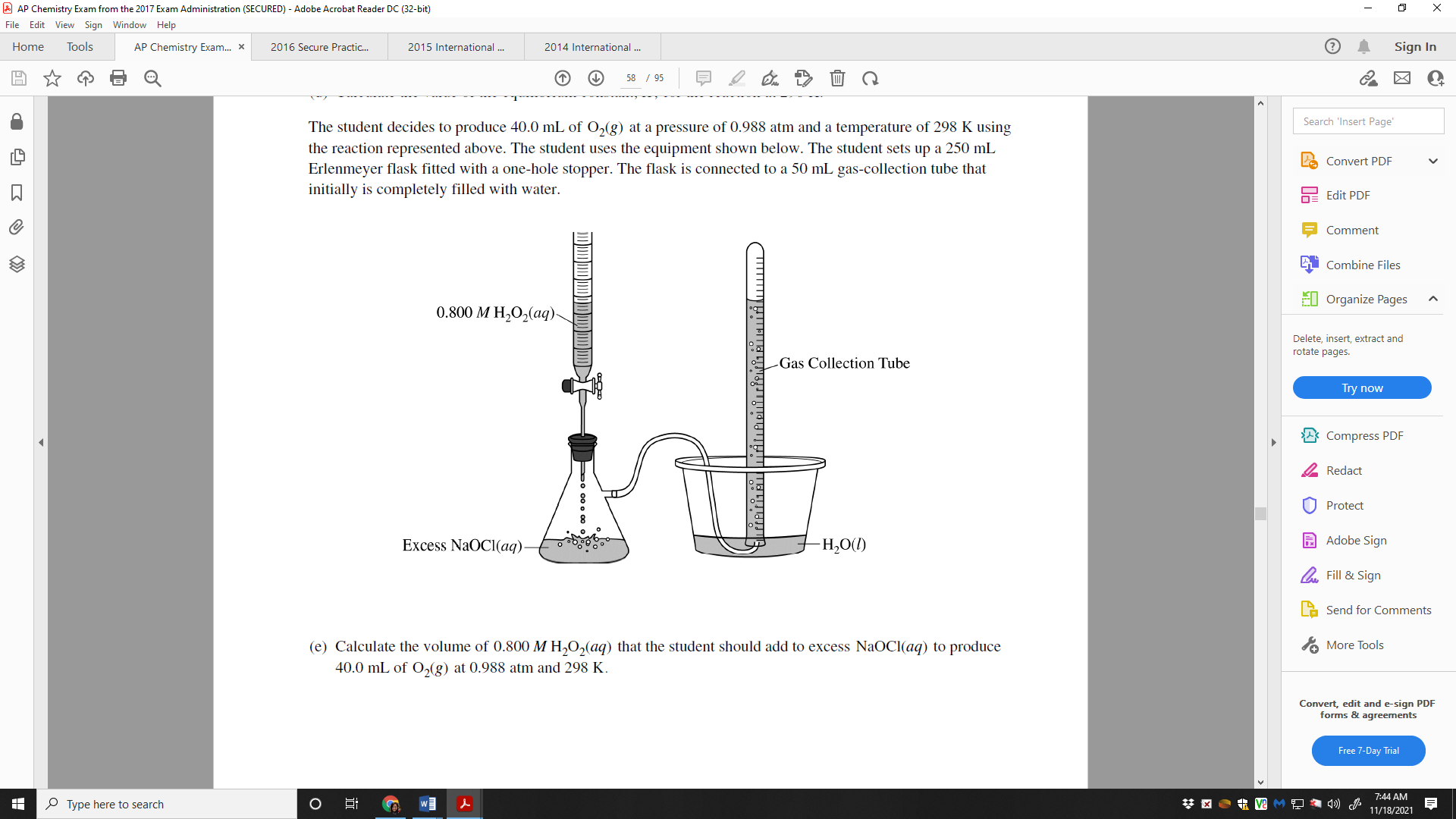
List all Bonds and Intermolecular Forces of Attraction contained in each of the following samples:

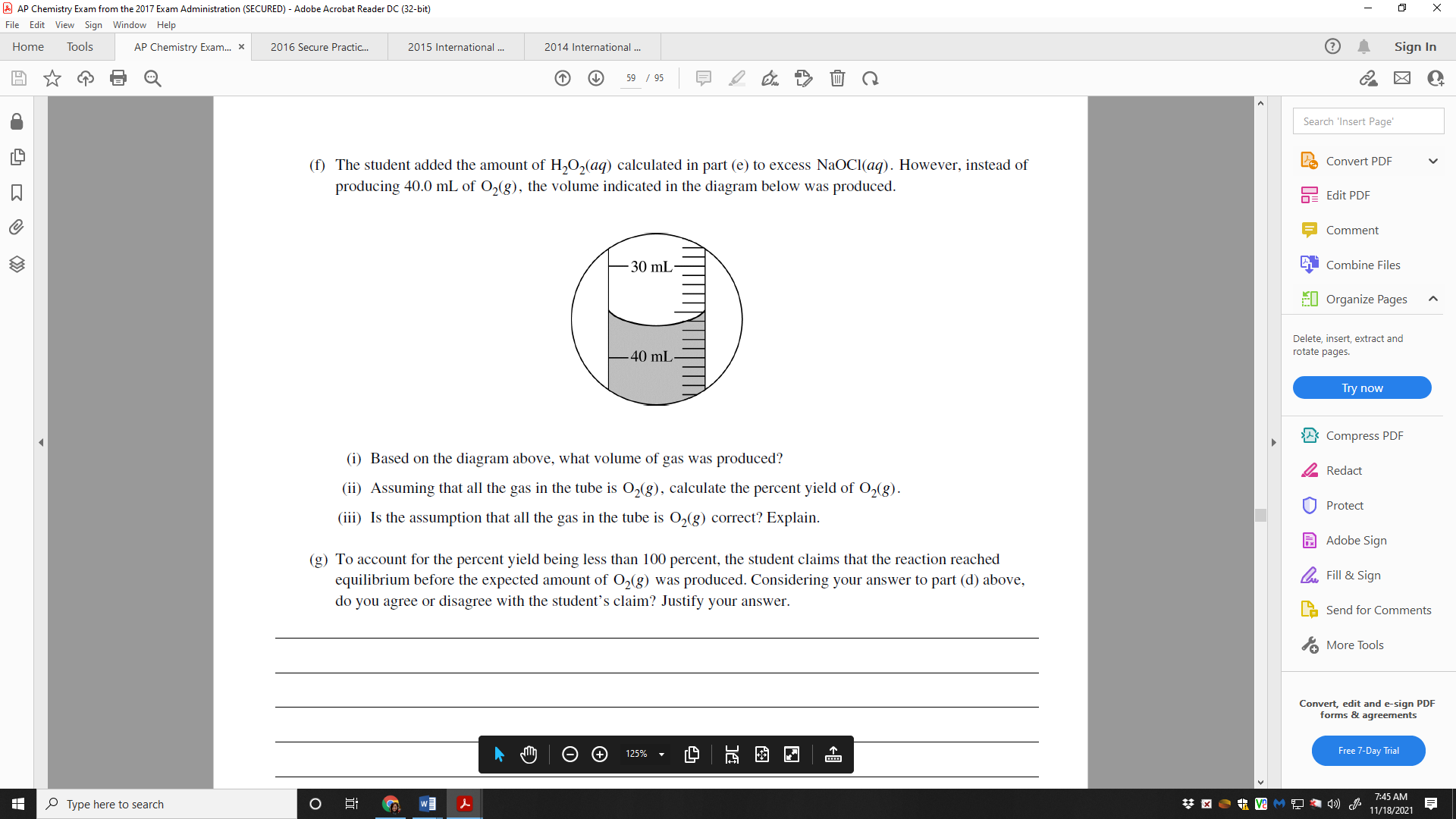
|  | Bonds | Forces |
| --- | --- | --- |
| Hydrogen Sulfide, H2S (g) |  |  |
| Water, H2O (l) |  |  |
| Bromine, Br2(l) |  |  |
| Iodine, I2(s) |  |  |
| carbon dioxide, CO2 (g) |  |  |
| Silicon dioxide, SiO2 (s) |  |  |
| Magnesium Oxide, MgO |  | No forces |
| Magnesium Oxide in water, MgO(aq) | skip this one |  |

Describe the following phenomena citing the types of forces, their strength and what it depends on.

* 1. H2O is a liquid and H2S is a gas at room temperature, although both O and S are in the same family.
  2. I2 has a higher normal boiling point than Br2, although both are halogens.
  3. SiO2 has a higher melting point than CO2, although Si and C are both in group 14.
  4. MgO has a higher solubility than Na2O.

**Unit 3**

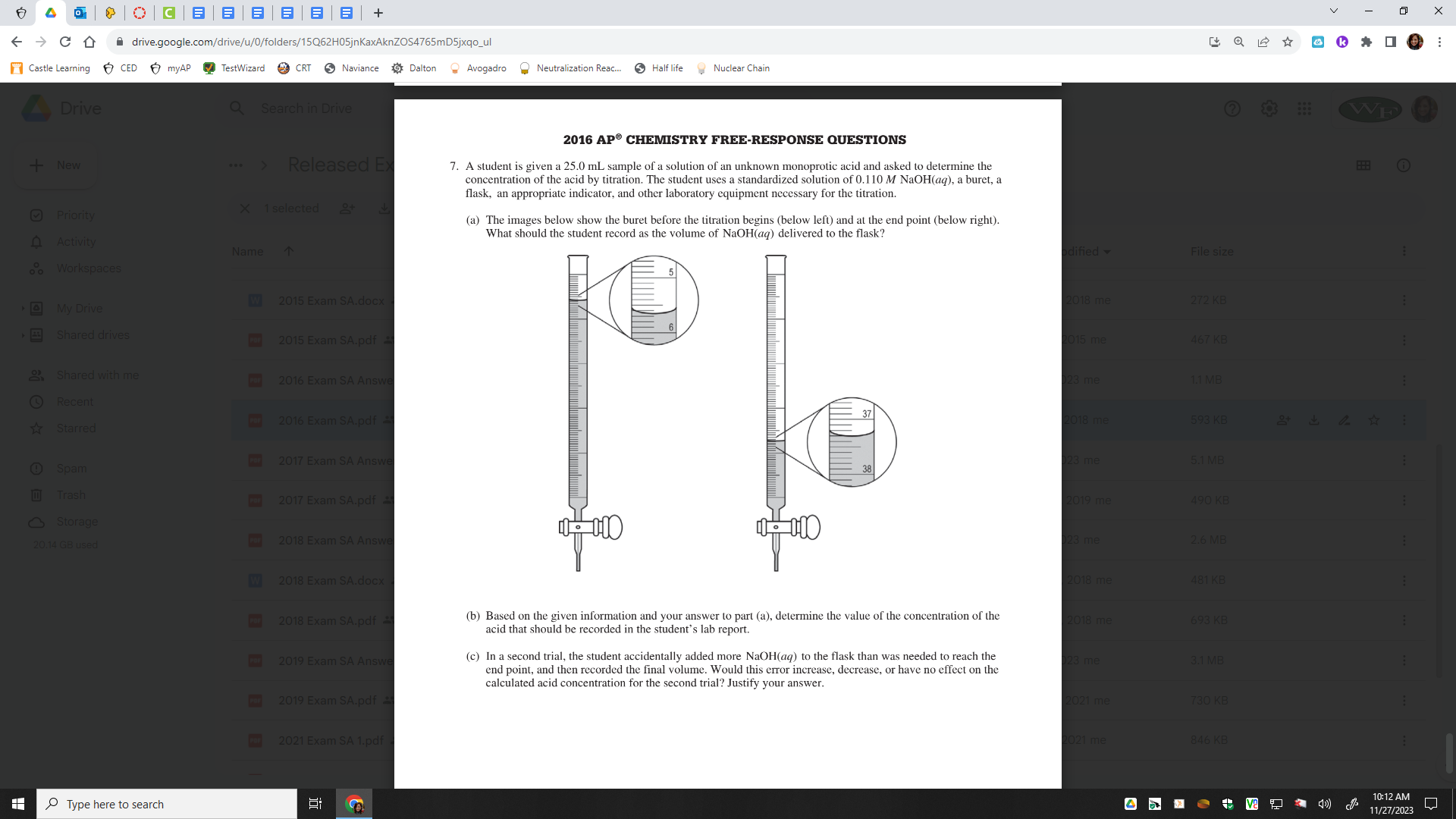




**Unit 4**

A student is given a 25.0 mL sample of a solution of an unknown monoprotic acid and asked to determine the concentration of the acid by titration. The student uses a standardized solution of 0.110 M NaOH(aq), a buret, a flask, an appropriate indicator, and other laboratory equipment necessary for the titration.

* 1. The images below show the buret before the titration begins (below left) and at the end point (below right). What should the student record as the volume of NaOH(aq) delivered to the flask?



* 1. Based on the given information and your answer to part (a), determine the value of the concentration of the acid that should be recorded in the student’s lab report.
  2. In a second trial, the student accidentally added more NaOH(aq) to the flask than was needed to reach the end point, and then recorded the final volume. Would this error increase, decrease, or have no effect on the calculated acid concentration for the second trial? Justify your answer.
  3. If the unknown turned out to be acetic acid, write the net ionic equation for this titration reaction.

**Unit 5**

The following equation represents the decomposition of N2O5(g) , for which the rate law is rate = k[ N2O5] A sample of pure N2O5(g) is placed in an evacuated container and allowed to decompose at a constant temperature of 300 K. The concentration of N2O5(g) in the container is measured over a period of time, and the measurements are recorded in the following table.

| Time (hr) | [ N2O5 ] M |
| --- | --- |
| 0 | 0.160 |
| 1.67 | 0.0800 |
| 3.33 | 0.0400 |
| 5.00 | 0.0200 |

1. Determine the value of the rate constant, k , for the reaction. Include units in your answer.
2. The following mechanism is proposed for the decomposition of N2O5(g)

Step 1: N2O5(g) → NO2(g) + NO3(g)

Step 2: NO2(g) + NO3(g) → NO2(g) + NO(g) + O2(g)

Step 3: N2O5(g) + NO(g) → 3 NO2(g)g

Identify which step of the proposed mechanism (1, 2, or 3) is the rate-determining step. Justify your

answer in terms of the rate law given.

1. If this experiment was repeated at the same temperature but with twice the initial concentration of N2O5(g) would the value of k increase, decrease, or remain the same? Explain your reasoning.

**Unit 6**

1. Calculate the Standard Enthalpy of reaction (ΔHr) below. The Enthalpy of formation of Iron (II) oxide equals -272kJ/mol and the enthalpy of formation of Iron (III) oxide equals -822kJ/mol.

4FeO(s) + O2(g) 🡪 2Fe2O3(s)

1. Calculate ΔH for the reaction 4NH3(g) + 5O2(g) 🡪 4NO(g) + 6H2O(g), from the following data.

N2(g) + O2(g) 🡪 2NO(g) ΔH = -180.5 kJ/mol

N2(g) + 3H2(g) 🡪 2NH3(g) ΔH = -91.8 kJ/mol

2H2(g) + O2(g) 🡪 2H2O(g) ΔH = -483.6 kJ/mol

**Unit 7**

H2(*g*) + I2(*g*) ↔ 2 HI(*g*)

1. Hydrogen gas reacts with iodine gas at constant temperature in a sealed rigid container. The gases are allowed to reach equilibrium according to the equation above. Which of the following best describes what will happen to the reaction immediately after additional iodine gas is added to the system?

(A) The rates of both the forward and reverse reactions decrease.

(B) The rates of both the forward and reverse reactions do not change.

(C) The rate of the forward reaction becomes greater than the rate of the reverse reaction.

(D) The rate of the forward reaction becomes less than the rate of the reverse reaction.

H2(*g*) + I2(*g*) ↔ 2 HI(*g*)

1. A 1.0 mol sample of H2(*g*) and a 1.0 mol sample of I2(*g*) are placed in a previously evacuated 1.0 L container and allowed to reach the equilibrium shown above. If the equilibrium concentration of HI(*g*) is 0.40 *M*, which of the following is the value of the equilibrium constant?

(A) 0.16 (B) 0.25 (C) 0.44 (D) 1.0

ICl(*g*) ↔ ½ I2(*g*) + ½ Cl2(*g*) *Keq* = 0.1

3. Based on the information above, what is the value of *Keq* for the reaction represented below?

I2(*g*) + Cl2(*g*) ↔ 2 ICl(*g*)

(A) 0.01 (B) 10 (C) 20 (D) 100

H2O(*g*) + CO(*g*) ↔ CO2(*g*) + H2(*g*) *Kp* = 136 at 500 K

4. A vessel initially contains H2O(*g*) at a partial pressure of 0.30 atm, CO(*g*) at a partial pressure of 0.10 atm, CO2(*g*) at a partial pressure of 1.5 atm, and H2(*g*) at a partial pressure 10. atm at 500 K. Which of the following occurs as the system approaches equilibrium at 500 K?

(A) The partial pressures of H2O(*g*) and CO(*g*) increase because *Q* > *Kp*.

(B) The partial pressures of H2O(*g*) and CO(*g*) increase because *Q* < *Kp*.

(C) The partial pressures of CO2(*g*) and H2(*g*) increase because *Q* > *Kp*.

(D) The partial pressures of CO2(*g*) and H2(*g*) increase because *Q* < *Kp*.

| Compound | *Ksp* |
| --- | --- |
| Fe(OH)2 | 4.9 × 10–17 |
| Cu(OH)2 | 1.6 × 10–19 |
| Co(OH)2 | 1.1 × 10–15 |

5. Which of the following ranks the compounds listed in the table above in order of increasing solubility?

(A) Fe(OH)2 < Cu(OH)2 < Co(OH)2 (C) Co(OH)2 < Fe(OH)2 < Cu(OH)2

(B) Fe(OH)2 < Co(OH)2 < Cu(OH)2 (D) Cu(OH)2 < Fe(OH)2 < Co(OH)2

CaF2(*s*) ↔ Ca2+(*aq*) + 2 F–(*aq*) Δ*H* > 0

6. Dissolution of the slightly soluble salt CaF2 is shown by the equation above. Which of the following changes

will decrease [Ca2+] in a saturated solution of CaF2, and why? (Assume that after each change some CaF2(*s*) remains in contact with the solution.)

(A)Allowing some of the water to evaporate from the solution, because more CaF2(*s*) will precipitate

(B)Adding 0.1 *M* HNO3(*aq*), because some F–(*aq*) ions will become protonated

(C)Adding 0.1 *M* NaNO3(*aq*), because additional liquid will dilute the solution

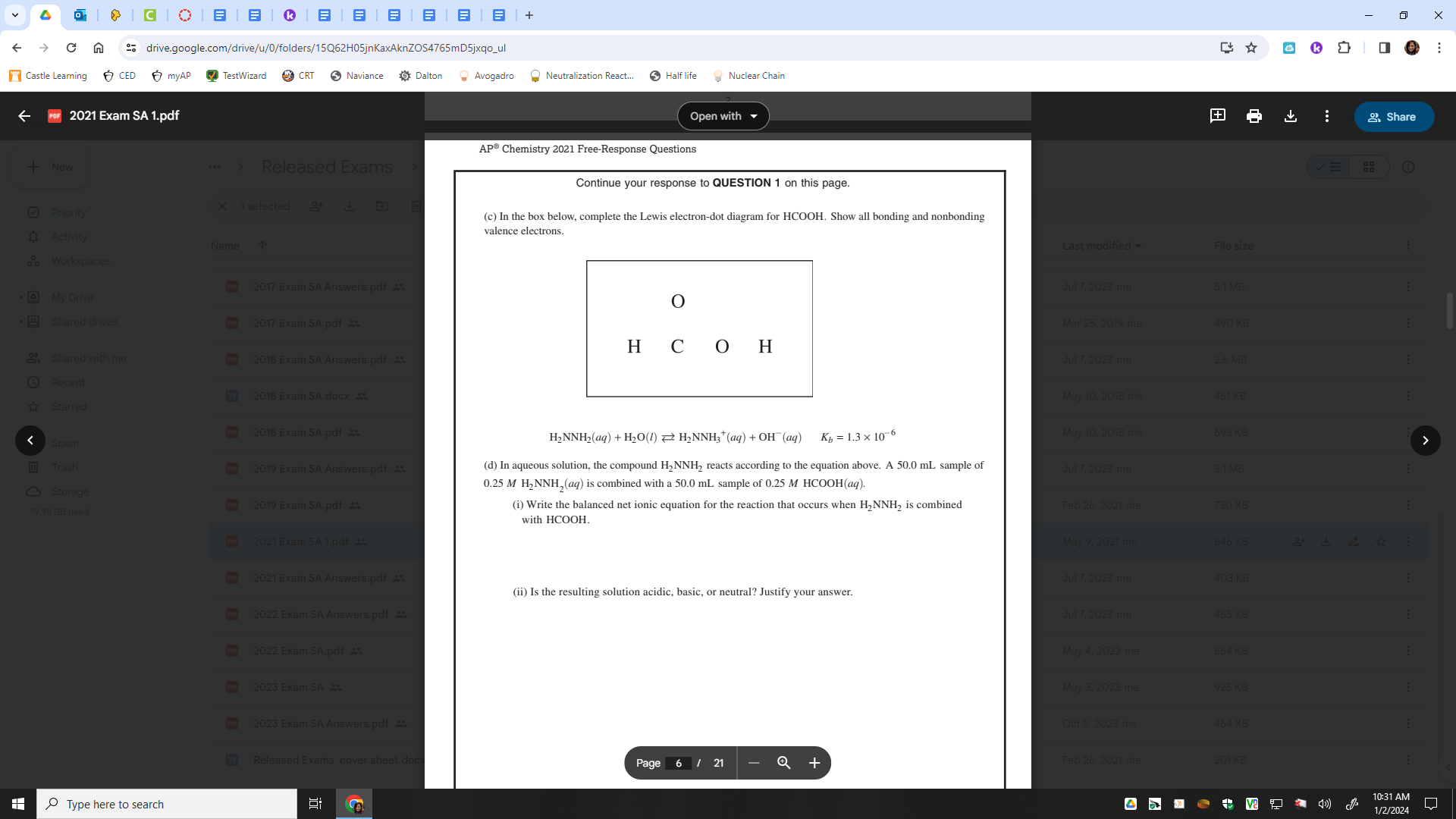
(D)Adding NaF(*s*), because the reaction will proceed toward reactants

**Unit 8**

HCOOH(aq) + H2O(l) ↔ H3O+(aq) + HCOO-(aq) Ka= 1.8x10-4

Methanoic acid, HCOOH, ionizes according to the equation above.

1. Write the expression for the equilibrium constant, Ka, for the reaction.
2. Calculate the pH of a 0.25 M solution of HCOOH.
3. In the box below, complete the Lewis electron-dot diagram for HCOOH. Show all bonding and nonbonding valence electrons.



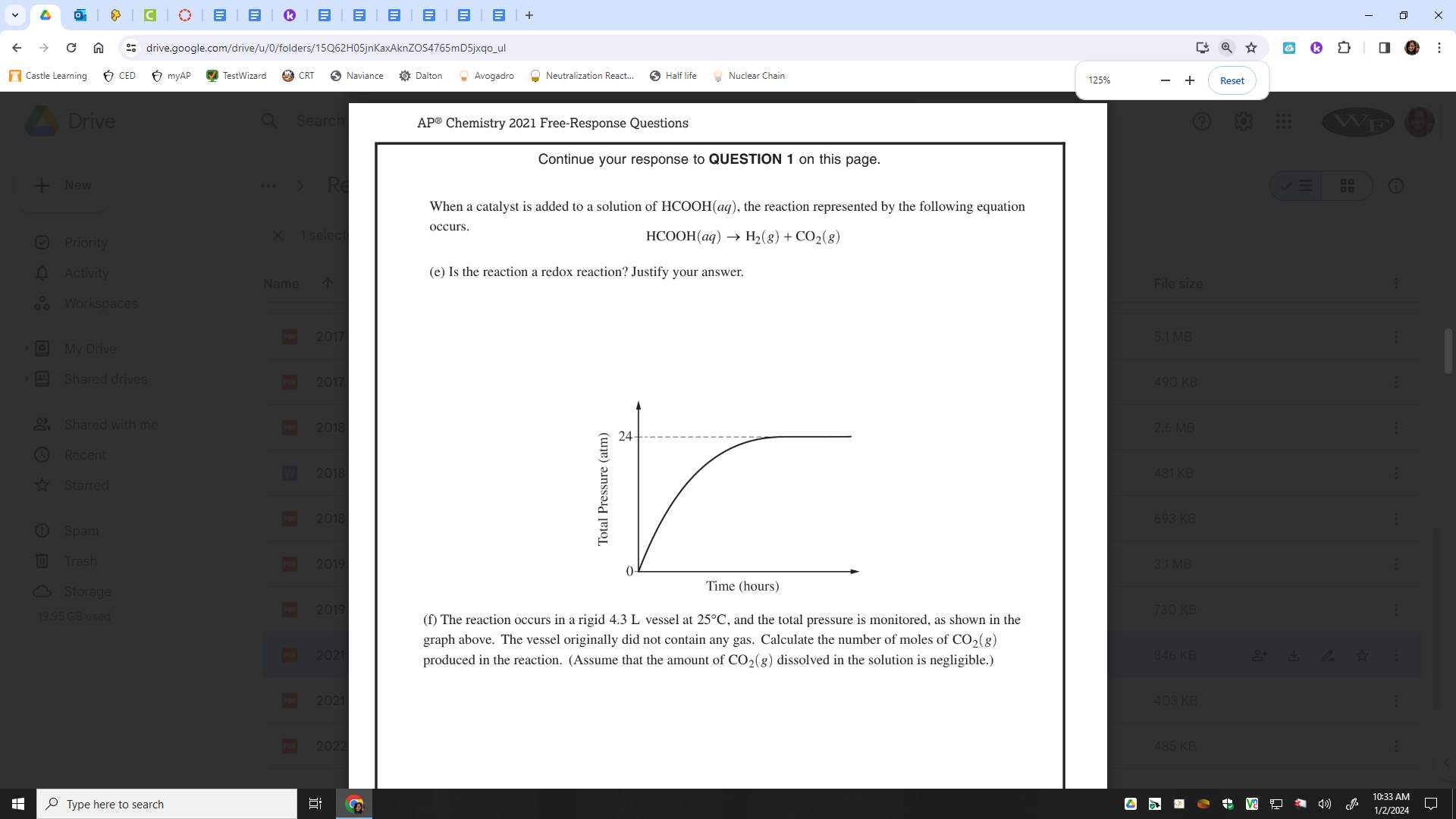
H2NNH2(aq) + H2O(l) ↔ H2NNH3+(aq) + OH-(aq) Kb = 1.3x10-6

1. In aqueous solution, the compound H2NNH2 reacts according to the equation above. A 50.0 mL sample of 0.25M H2NNH2(aq) is combined with a 50.0 mL sample of 0.25 M HCOOH(aq) .
   1. Write the balanced net ionic equation for the reaction that occurs when H2NNH2 is combined with HCOOH.
   2. Is the resulting solution acidic, basic, or neutral? Justify your answer.

When a catalyst is added to a solution of HCOOH(aq), the reaction represented by the following equation

occurs. HCOOH(aq) → H2(g) + CO2(g)

1. Is the reaction a redox reaction? Justify your answer.



1. The reaction occurs in a rigid 4.3 L vessel at 25°C, and the total pressure is monitored, as shown in the graph above. The vessel originally did not contain any gas. Calculate the number of moles of CO2(g) produced in the reaction. (Assume that the amount of CO2(g) dissolved in the solution is negligible.)

**Unit 9a**

2 H2O2(*aq*) → 2 H2O(*l*) + O2(*g*) Δ*G*° = –234 kJ/mol*rxn*

1. The value of Δ*G*° for the reaction represented above implies that the decomposition of H2O2(*aq*) is thermodynamically favorable. However, H2O2(*aq*) is typically stable for up to a year stored in a dark bottle at 298 K. The best explanation for this observation is that the decomposition reaction

(A) is only thermodynamically favorable in the presence of a catalyst

(B) occurs with an increase in entropy because O2(*g*) is a product

(C) is reversible and H2O2(*aq*) is produced almost as fast as it decomposes

(D) has a slow rate at 298 K because the activation energy is relatively high

2 FeO(*s*) ↔ 2 Fe(*s*) + O2(*g*) *Keq* = 1 × 10–6 at 1000 K

CO2(*g*) ↔ C(*s*) + O2(*g*) *Keq* = 1 × 10–32 at 1000 K

1. The formation of Fe(*s*) and O2(*g*) from FeO(*s*) is not thermodynamically favorable at room temperature. In an effort to make the process favorable, C(*s*) is added to the FeO(*s*) at elevated temperatures. Based on the information above, which of the following gives the value of *Keq* and the sign of Δ*G*° for the reaction represented by the equation below at 1000 K?

2 FeO(*s*) + C(*s*) ↔ 2 Fe(*s*) + CO2(*g*)

|  | *Keq* | Δ*G*° |
| --- | --- | --- |
| (A) | 1 × 10–38 | Positive |
| (B) | 1 × 10–38 | Negative |
| (C) | 1 × 1026 | Positive |
| (D) | 1 × 1026 | Negative |

1. The data in the table below were determined at 25ºC. CO(g) + 2H2(g) 🡪 CH3OH(l)

|  | ΔHº kJ/mol | ΔGfº kJ/mol | ΔSfº J/molK |
| --- | --- | --- | --- |
| CO(g) | -110.5 | -137.3 | +197.9 |
| CH3OH(l) | -238.6 | -166.2 | +126.8 |
| CO(g) + 2H2(g) 🡪 CH3OH(l) | -128.1 |  |  |

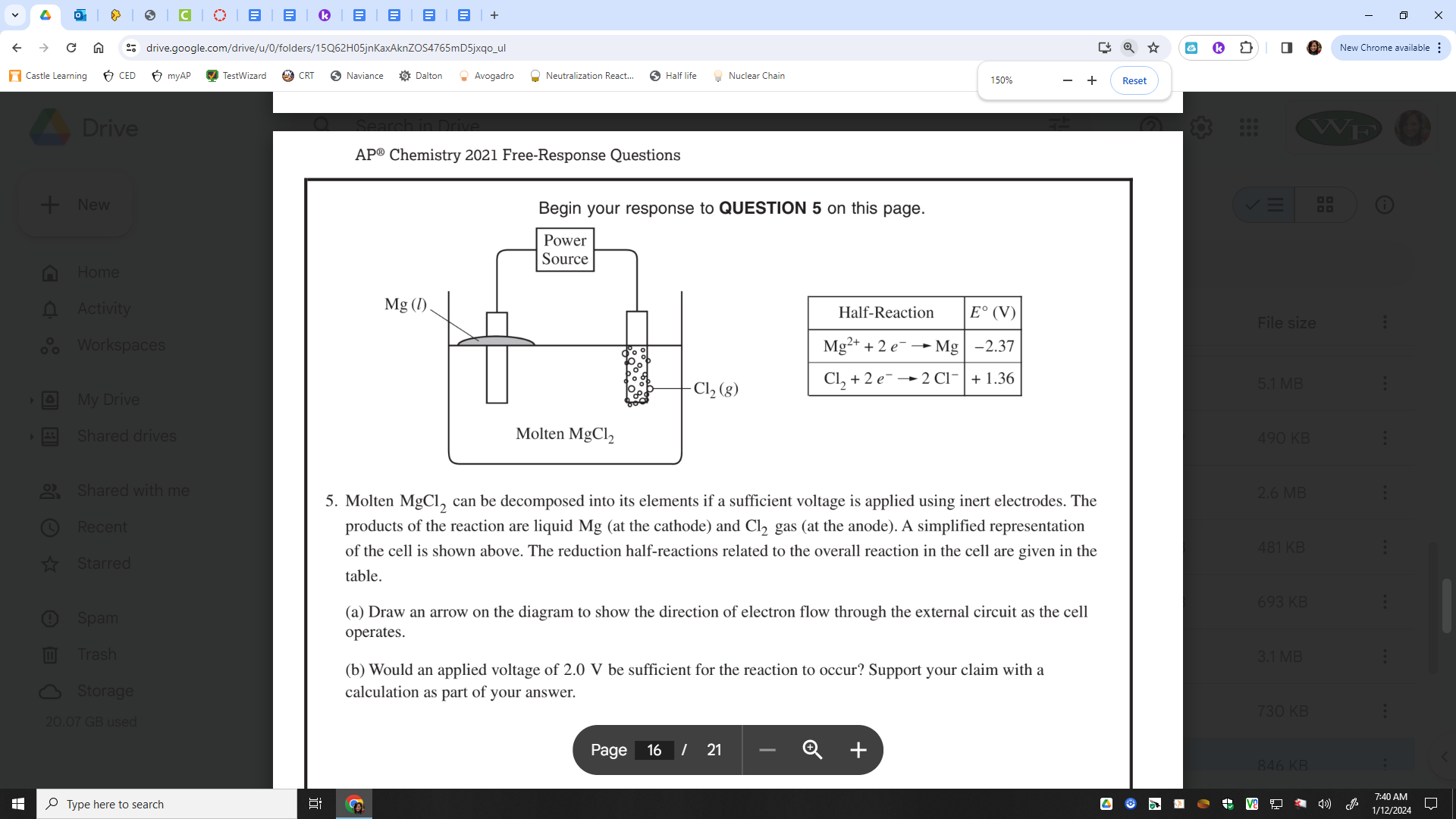
a. Calculate the ΔGº for the reaction above.

b. Calculate the ΔSº for the reaction above.

c. In the table above there are no values given for Hydrogen’s ΔHº, ΔGº or ΔSº. What are their

values at 25ºC?

**Unit 9b**



Molten MgCl2 can be decomposed into its elements if a sufficient voltage is applied using inert electrodes. The products of the reaction are liquid Mg (at the cathode) and Cl2 gas (at the anode). A simplified representation of the cell is shown above. The reduction half-reactions related to the overall reaction in the cell are given in the table.

1. Draw an arrow on the diagram to show the direction of electron flow through the external circuit as the cell operates.
2. Would an applied voltage of 2.0 V be sufficient for the reaction to occur? Support your claim with a calculation as part of your answer.
3. If the current in the cell is kept at a constant 5.00 amps, how many seconds does it take to produce 2.00g of Mg(l) at the cathode?
4. If the Mg cathode was larger, how would the increase in Mg mass affect the voltage needed for the reaction to occur? Justify your answer.