State of Israel
Ministry of Education
Exam Type: *Bagrut*
Exam date: Summer 2020
Exam number: 37381
Attachments: (1) Periodic table
(2) Electronegativity table
(3) Formulas for calculations
(4) Functional groups
English translation (3)

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תש"ף, 2020
מספר השאלון: 37381
נספחים: (1) הטבלה המחזורית
(2) טבלת אלקטרושליליות
(3) נוסחאות לחישובים
(4) קבוצות פונקציונליות
תרגום לאנגלית (3)

Chemistry

כימיה

Instructions for examinees

א. Duration of the exam: Three hours

ב. Exam structure and breakdown of points:
This exam has two parts.

Part One	— Required	—	40 points
Part Two	—	—	60 points
	Total	—	100 points

ג. Material that may be used during the exam:
(1) A calculator (graphing calculators are permitted).
(2) Formulas and data sheets (attached)
(3) A Hebrew-foreign language/
foreign language-Hebrew dictionary.

ד. Special instructions:
(1) **Note:** In Part One, there are nine **required** questions.
For each of Questions 1-8, four possible answers are given and you must choose the correct answer.
Mark the correct answers on the answer sheet found at the end of the answer booklet (page 19).
You must answer all of the items in Question 9.
(2) In Part Two, there are five questions. You must answer three of them.

הוראות לנבחן

א. משך הבחינה: שלוש שעות.

ב. מבנה השאלון ומפתח ההערכה:
בשאלון זה שני פרקים.

פרק ראשון	– חובה	– 40 נקודות
פרק שני		– 60 נקודות
סך הכל		– 100 נקודות

ג. חומר עזר מותר בשימוש:
(1) מחשבון (כולל מחשבון גרפי).
(2) דפי נוסחאות ונתונים (מצורפים)
(3) מילון עברי-לועזי / לועזי-עברי.

ד. הוראות מיוחדות:
(1) **שים לב:** בפרק הראשון יש תשע שאלות **חובה**.
בכל אחת מן השאלות 1-8 מוצגות ארבע תשובות, ומהן עליך לבחור בתשובה הנכונה.
את התשובות הנכונות עליך לסמן בתשובון שבסוף מחברת הבחינה (עמוד 19).
בשאלה 9 יש לענות על כל הסעיפים.
(2) בפרק השני יש חמש שאלות. עליך לענות על שלוש מהן.

Write in the answer booklet only. Write the word "טיוטה" at the top of each page you use as a draft page. If you write any draft material outside the answer booklet, your exam may be disqualified.

כתוב במחברת הבחינה בלבד. רשום "טיוטה" בראש כל עמוד המשמש טיוטה. כתיבת טיוטה בדפים שאינם במחברת הבחינה עלולה לגרום לפסילת הבחינה.

Good Luck!

בהצלחה!

Questions

Part One (40 points)

Answer the eight questions 1-8 (each question – 2.5 points).

Before you answer a question, read all the possible answers.

Each question is given four possible answers. Choose the correct one.

* Mark the answer you chose on the answer sheet on the inside cover at the end of the answer booklet (page 19).
* For each question, use a pen to mark an X in the box below the letter (א-ד) that represents the answer you chose.
* Mark an X in only one box for each question.
* If you want to erase your answer, fill in the whole box like this: ■ .
* Do **not** use White-Out to erase answers.
* **Note: In order to limit the need to erase answers on the answer sheet, we recommend that you first mark the correct answers inside the exam booklet itself and only later mark them on the answer sheet.**

1. Which electron dot diagram [נוסחת ייצוג אלקטרונית] correctly represents the particles of the compound $CaC\ell_{2(s)}$?

א. $[Ca]^{2+}$ and $[:\ddot{C}\ell:]^-$

ב. $[Ca:]^{2+}$ and $[:\ddot{C}\ell\cdot]$

ג. $Ca:$ and $:\ddot{C}\ell\cdot$

ד. $:\ddot{C}\ell:$ Ca $:\ddot{C}\ell:$

2. The first ionization energy [אנרגיית יינון] of an oxygen atom, O, is higher than the first ionization energy of a sulfur atom, S.

What causes this?

א. The oxygen atom has fewer populated energy levels than the sulfur atom.

ב. The electronegativity of the oxygen atom is higher than the electronegativity of the sulfur atom.

ג. The number of protons in an oxygen atom is smaller than the number of protons in a sulfur atom.

ד. Oxygen is located above sulfur in the periodic table.

/continued on page 3/

3. CH_4 , $CC\ell_4$, $CH_2FC\ell$, CF_4 are the molecular formulas of four molecules.
Each of these molecules has a tetrahedral spatial structure.
The following four statements, א-ד, are related to covalent bonds in molecules and molecule polarity [קוטביות].
Which statement is correct?

א. In a CF_4 molecule all covalent bonds are nonpolar and the molecule is nonpolar.
ב. In a CH_4 molecule all covalent bonds are nonpolar and the molecule is polar.
ג. In a $CC\ell_4$ molecule all covalent bonds are polar and the molecule is nonpolar.
ד. In a $CH_2FC\ell$ molecule all covalent bonds are polar and the molecule is nonpolar.

4. In container A there are 22 grams of the gas carbon dioxide, $CO_{2(g)}$.
In container B there are 22 grams of the gas propane, $C_3H_{8(g)}$.
The temperature in both containers is the same, but the pressure in container A is smaller than in container B.
Which statement is correct?

א. The number of moles of gas in container A is larger than the number of moles of gas in container B.
ב. The number of moles of gas in container A is smaller than the number of moles of gas in container B.
ג. The volume of container A is smaller than the volume of container B.
ד. The volume of container A is larger than the volume of container B.

5. A beaker contained 400 ml of a potassium bromide solution, $KBr_{(aq)}$, with a concentration of 0.2M. 400 ml of a magnesium bromide solution, $MgBr_{2(aq)}$, with a concentration of 0.1M, were added to the beaker and the two solutions were mixed.
The following four statements, I-IV, relate to data about the beaker <u>after mixing</u>.

I The number of moles of bromide ions, $Br^-_{(aq)}$, in the beaker is 0.12 moles.
II The number of moles of bromide ions, $Br^-_{(aq)}$, in the beaker is 0.16 moles.
III The concentration of bromide ions, $Br^-_{(aq)}$, in the beaker is 0.3M.
IV The concentration of bromide ions, $Br^-_{(aq)}$, in the beaker is 0.2M.

Which two statements are correct?

א. statements I and III
ב. statements I and IV
ג. statements II and IV
ד. statements II and III

/continued on page 4/

6. The following three metals, zinc, $Zn_{(s)}$, tin, $Sn_{(s)}$, and copper, $Cu_{(s)}$, are arranged below in order of their relative ability to reduce:

$$Zn_{(s)} > Sn_{(s)} > Cu_{(s)}$$

Three separate containers, A, B, and C, hold three solutions that contain ions of the metals and other substances. There is a different solution in each container, as shown in the following table.

	Container A	**Container B**	**Container C**
Positive ions in the solution	Zinc ions $Zn^{2+}_{(aq)}$	Tin ions $Sn^{2+}_{(aq)}$	Copper ions $Cu^{2+}_{(aq)}$

One of the metals zinc, $Zn_{(s)}$, tin, $Sn_{(s)}$ or copper, $Cu_{(s)}$, is added to one of the containers A, B, or C.

A reaction occurs and one of its products is the metal tin, $Sn_{(s)}$.

Which metal and which solution participated in this reaction?

א. The metal copper, $Cu_{(s)}$, reacted with the solution in container B.

ב. The metal zinc, $Zn_{(s)}$, reacted with the solution in container C.

ג. The metal copper, $Cu_{(s)}$, reacted with the solution in container A.

ד. The metal zinc, $Zn_{(s)}$, reacted with the solution in container B.

7. The following equation describes the reaction of methylamine, $CH_3NH_{2(g)}$, with water.

$$CH_3NH_{2(g)} + H_2O_{(\ell)} \longrightarrow CH_3NH^+_{3(aq)} + OH^-_{(aq)}$$

Which statement is correct?

א. In the given reaction, water, $H_2O_{(\ell)}$, reacts as a base.

ב. In the given reaction, methylamine, $CH_3NH_{2(g)}$, reacts as a base.

ג. At the end of the reaction an acidic solution is obtained (pH<7).

ד. In this reaction electrons pass from the methylamine molecules, CH_3NH_2, to the water molecules.

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8. The diagram below describes changes in enthalpy.

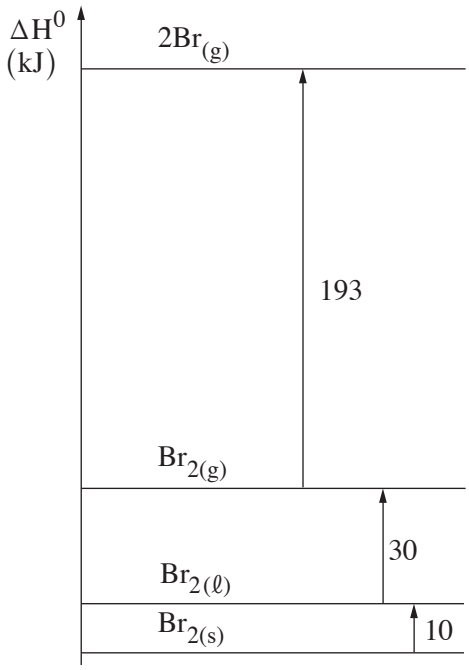
What is the enthalpy of evaporation of bromine?

א. $10\frac{kJ}{mol}$

ב. $30\frac{kJ}{mol}$

ג. $40\frac{kJ}{mol}$

ד. $223\frac{kJ}{mol}$



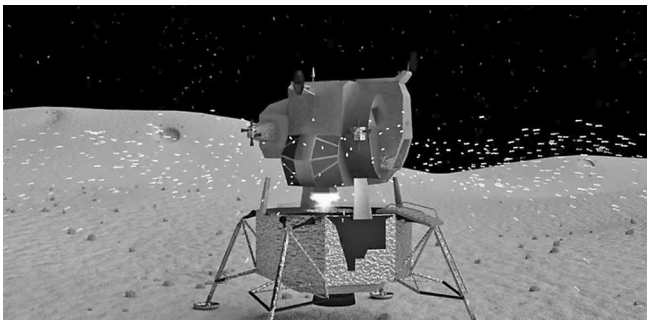
/continued on page 6/

Analysis of an excerpt from a Scientific Article - Required

9. Read the passage below and answer all the items א-ה that follow (required question - 20 points).

One small step on the moon, one giant leap for chemistry

The first time that astronauts landed on the moon and returned safely to Earth was on the Apollo 11 mission, on July 20th, 1969. Since then, five manned Apollo missions have landed on the moon. The US National Aeronautics and Space Administration (NASA) recently announced its intention of landing astronauts on the moon again in 2024.
To take off from the moon and return to Earth, the moon's gravity must be overcome. Spacecraft rocket engines use hypergolic fuels, which are liquid fuels that react on contact, at room temperature, without requiring heat or a spark to initiate the reaction. The hypergolic fuels used on the Apollo missions were a liquid mixture of hydrazine, $N_2H_{4(\ell)}$, and methylhydrazine, $NH(CH_3)NH_{2(\ell)}$, stored in one tank, and $N_2O_{4(\ell)}$, which was stored at high pressure in another tank. When these liquids came into contact with each other, the instant reaction generated a jet of extremely hot, pressurized gas sufficient to lift the spacecraft off the moon. After liftoff, sparks were emitted which started a fire on the launchpad that had remained on the moon surface. While they were on the moon, the astronauts collected soil samples which are still being used today to study the composition, age, and formation of the moon.



Retrieved from: https://youtube.com/watch?v=sj6a0Wrrh1g

The substances in moon soil are different from the substances that are common on Earth. For example, on Earth Fe^{2+} ions are oxidized by the oxygen in the air and become Fe^{3+} ions. This process does not take place on the moon at all, so there are no compounds containing Fe^{3+} ions in moon soil, only Fe^{2+} compounds.
The soil samples that the astronauts brought back from the moon also contained the rare isotope $^{182}_{74}W$. The isotope $^{182}_{74}W$ is formed on the moon surface when the isotope $^{182}_{72}Hf$ radioactively decomposes. Based on the information scientists had about the isotope $^{182}_{74}W$, they concluded that the moon had been formed about 60 million years after the solar system had formed.
Many countries in the world are planning exploratory missions to the moon. Despite the large amount of knowledge we have today about the chemistry of the moon, new discoveries can still be expected in the future.

Retrieved from: https://chemistryworld.com/2128.tag

/continued on page 7/

א. One of the components of the hypergolic fuel is a liquid mixture of hydrazine and methylhydrazine.

Provide a complete structural formula of the hydrazine molecule, N_2H_4, and a complete structural formula for the methylhydrazine molecule, $NH(CH_3)NH_2$.

ב. According to the passage, when the liquids $N_2H_{4(\ell)}$, $NH(CH_3)NH_{2(\ell)}$ and $N_2O_{4(\ell)}$ come in contact with each other an instant reaction occurs.

The following two statements, i and ii, relate to the reaction that occurs. Determine whether each statement is true or false. Explain your answer in each case, based on the passage.

i $\Delta H^0 < 0$ for the reaction that occurred.

ii The activation energy [אנרגיית שפעול] for the reaction that occurred is high.

ג. The reaction of $N_2O_{4(\ell)}$ with $N_2H_{4(\ell)}$ produces $H_2O_{(g)}$ and $N_{2(g)}$.

i Formulate and balance the reaction equation.

ii In this reaction, 10 kg of $N_2H_{4(\ell)}$ react completely. What is the <u>total</u> number of moles of gas emitted in this reaction? Provide detailed calculations.

ד. Which iron compound might be found on the moon: $FeS_{(s)}$ or $Fe_2S_{3(s)}$?
Explain your answer based on the passage.

ה. The isotope $^{182}_{74}W$ derives from the isotope $^{182}_{72}Hf$ in two successive steps of radioactive decay [התפרקות] — Step 1 and Step 2.

Isotope A is a product of Step 1 and a reactant in Step 2.

1. $^{182}_{72}Hf \longrightarrow A$ + beta radioactive radiation
2. $A \longrightarrow {}^{182}_{74}W$ + ____ radioactive radiation

i What is the atomic number of Isotope A?

ii What is the mass number of Isotope A?

iii What is the symbol of the element A?

iv What type of radioactive radiation is emitted in Step 2?

/continued on page 8/

Part 2 (60 points)

Answer three of the questions 10-14 (each question — 20 points).

Basic concepts, and structure and bonding

10. This question relates to the structure and properties of two molecular substances, A and B, placed in two separate containers.

The following table shows data about the two substances:

Substance	Melting point (°C)	Boiling point (°C)
A	-45	157
B	-114	78

א. What is the state of matter [מצב צבירה] of each of the substances A and B at room temperature (25°C)? Explain.

ב. The figures below provide a partial description of the microscopic structure of the two substances A and B at room temperature.

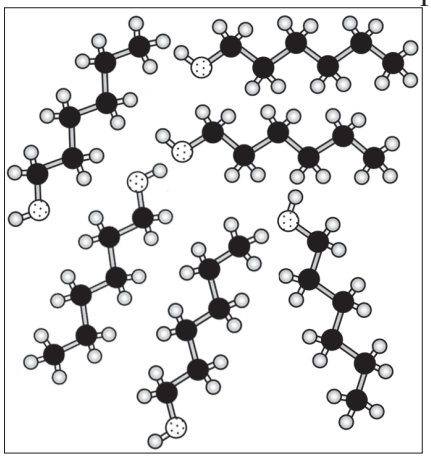


Figure 2

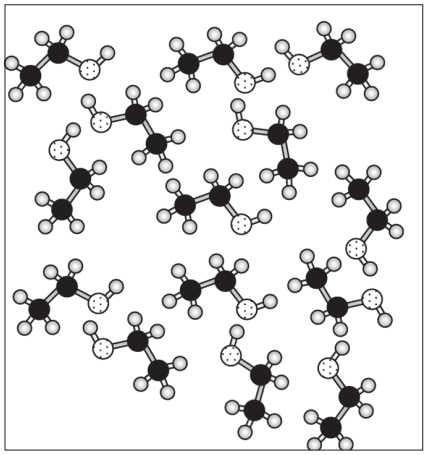


Figure 1

Legend
C – carbon atom
O – oxygen atom
H – hydrogen atom

i Read the following four statements, a-d. Determine whether each statement is true or false.

a. The molecules of both substances are composed of the same type of atoms.

b. The functional group of substance A molecules is different from the functional group of substance B molecules.

c. The number of carbon atoms in substance A molecules is different from the number of carbon atoms in substance B molecules.

d. The type of molecular motion in both substances A and B is vibration only.

ii Based on the interactions between the molecules, determine which of the figures (Figure 1 or Figure 2) describes the microscopic structure of substance A. Explain.

/continued on page 9/

ג. An identical volume of water was mixed into the container with substance A and into the container with substance B. Figures 3 and 4 describe the microscopic structure of the **mixture** of each of the substances with water after stirring.

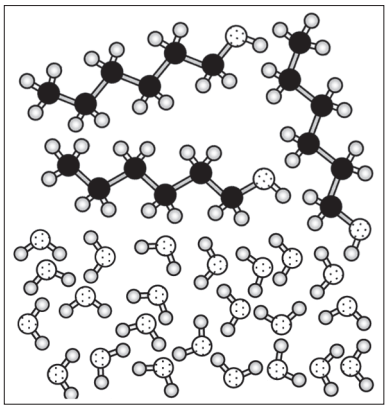


Figure 4

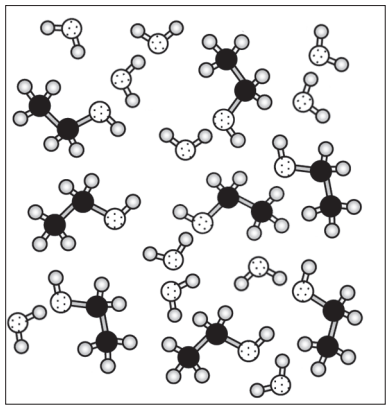


Figure 3

i Determine which figure (Figure 3 or Figure 4) is a microscopic description of a solution. Explain your answer.

ii Formulate the reaction of dissolution in water of the substance that matches the figure you selected in Sub-item ג.i.

iii Explain why the other substance did not dissolve in water. Discuss interactions between particles in your answer.

iv What is the macroscopic difference between the two mixtures described in Figures 3 and 4?

/continued on page 10/

Oxidation-reduction and stoichiometry

11. Israel is one of the world's largest producers of the element bromine, $Br_{2(\ell)}$, and its compounds.

In Reaction (1) below bromine reacts with water to produce a solution of $HBrO_{(aq)}$ which can be used for disinfection and bleaching.

(1) $Br_{2(\ell)} + H_2O_{(\ell)} \longrightarrow HBrO_{(aq)} + HBr_{(g)}$

א. i Determine whether $Br_{2(\ell)}$ reacts in Reaction (1) only as an oxidizer, only as a reducer, or as both an oxidizer and a reducer. Explain your answer.

A reducer was added to a solution of $HBrO_{(aq)}$. A reaction occurred.

ii Determine which ions will be found in the solution when the reaction is complete, $Br^-_{(aq)}$ ions or $BrO^-_{3(aq)}$ ions. Explain your answer.

In Reaction (2) below $BrO^-_{3(aq)}$ ions are produced.

(2) $3BrO^-_{(aq)} \longrightarrow 2Br^-_{(aq)} + BrO^-_{3(aq)}$

ב. i How many moles of electrons were transferred in a reaction in which 1 mole of $BrO^-_{3(aq)}$ ions was produced? Explain.

$BrO^-_{3(aq)}$ ions are toxic. The highest permitted concentration of $BrO^-_{3(aq)}$ in water is 0.01 microgram per liter.

Given: 1 microgram = 1×10^{-6} grams.

ii What is the maximum permitted number of $BrO^-_{3(aq)}$ ions in 1 liter of water? Provide detailed calculations.

Given: There are 6.02×10^{23} particles in one mole of particles.

/continued on page 11/

The element bromine is toxic and hazardous, and is therefore stored in closed storage tanks. If there is a leak, the bromine vapor is reacted with ammonia, $NH_{3(g)}$. Reaction (3) occurs.

(3) $3Br_{2(g)} + 8NH_{3(g)} \longrightarrow N_{2(g)} + 6NH_4Br_{(s)}$

ג. i Determine whether $NH_{3(g)}$ reacts in Reaction (3) only as an oxidizer, only as a reducer, or both as an oxidizer and a reducer.

ii How many kilograms of $NH_4Br_{(s)}$ are produced when 8.0 kg of bromine vapor are reacted with ammonia? Provide detailed calculations.

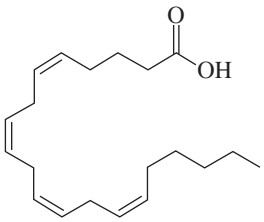
iii What volume, at STP, of the gas nitrogen, $N_{2(g)}$, is produced when 8.0 kg of bromine vapor are reacted with ammonia? Provide detailed calculations.
Given: The molar volume of a gas at STP is 22.4 liters.

/continued on page 12/

Food chemistry

12. Algae (seaweed) are rich in nutrients. They contain all the basic food groups [אבות המזון] and many vitamins and minerals.

The following table shows data for two essential fatty acids found in algae:

Fatty acid	Arachidonic acid (ARA)	Eicosapentaenoic acid (EPA)
Melting point (°C)	-49	-54
Skeletal formula of the molecule		----------
Abbreviated notation of fatty acid	----------	C20: 5ω3 cis cis cis cis cis

א. i What are essential fatty acids?

ii Provide the abbreviated notation for the fatty acid ARA.

iii Provide the skeletal formula of a molecule of the fatty acid EPA.

ב. The melting point of stearic acid (St), C18:0, is 69.6°C.

Stearic acid has a much higher melting point than the fatty acids above, ARA and EPA.

Explain this statement. Your answer must refer to the interactions between the molecules.

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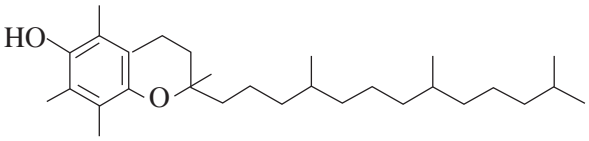
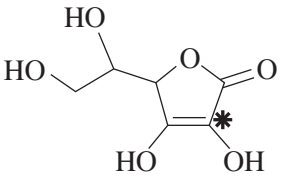
When manufacturing a dietary supplement [תוסף מזון] from algae, it is advisable to add antioxidants [נוגדי חמצון] to prevent the essential fatty acids in the algae from becoming oxidized, so they can be stored for a long time.

The skeletal formulas of the vitamins C and E (which function as antioxidants) are shown below:



Vitamin E



Vitamin C

ג. The carbon atom that is labeled with a ✱ in the skeletal formula of vitamin C participates in the process in which vitamin C serves as an antioxidant.

i What is the oxidation level of the carbon atom labeled with a ✱ in the skeletal formula of vitamin C?

ii Consider the statements a-c below. Indicate which statements correctly describe the antioxidant activity of vitamin C.

a. The oxidation level of the carbon atom labeled with a ✱ goes up.

b. Vitamin C reacts as an oxidizer in oxidation-reduction processes.

c. Vitamin C prevents undesirable oxidation processes in substances.

iii Determine which vitamin, C or E, is <u>less</u> suitable for use as an antioxidant that is soluble in a mixture of the given fatty acids. Explain your answer.

ד. One of the important minerals in algae (seaweed) is the compound KI. This compound is a source of iodide I^- ions.

According to Ministry of Health guidelines, the recommended daily intake of iodine is 150 micrograms of iodide ions.

Nori seaweed sheets are used to prepare sushi and other foods. One sheet of nori seaweed weighing 2.5 grams contains 45 micrograms of iodide ions.

Determine whether a portion of soup prepared from 10 grams of nori seaweed sheets contains more or less than the recommended daily intake of iodide ions, or the exact recommended daily intake. <u>Provide detailed calculations and explain</u>.

/continued on page 14/

Acids and bases

13. Students conducted a laboratory experiment. They marked a beaker with the letter A, and dissolved in it 3.6 grams of solid sodium hydroxide, $NaOH_{(s)}$, in water. The volume of the solution in beaker A was 600 ml.

א. i Formulate the equation of the dissolution process that took place when the solution in beaker A was prepared.

ii Was the pH of the solution in beaker A lower than 7, equal to 7, or higher than 7? Explain.

The students divided the solution in beaker A equally between three other beakers I, II, and III so that each of the beakers contained 200 ml of solution, as shown in Figure 1.

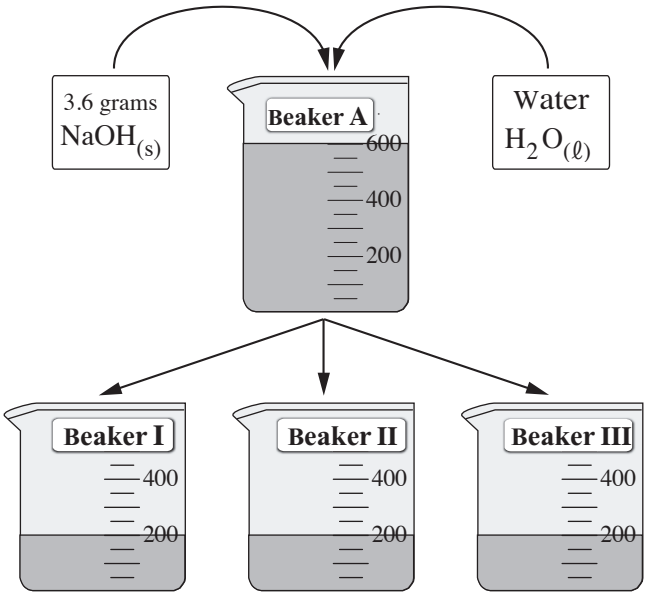


Figure 1

/continued on page 15/

ב. i The four statements, a-d, below relate to the solutions in beakers I, II, and III that are described in Figure 1.

Indicate which of the four statements a-d are <u>true</u>.

a. The number of moles of solute in each beaker is smaller than the number of moles of solute in the solution that had been prepared in beaker A.

b. The number of moles of solute in each beaker is equal to the number of moles of solute that was in the solution that had been prepared in beaker A.

c. The concentration of the solution in each beaker is smaller than the concentration of the solution that had been prepared in beaker A.

d. The concentration of the solution in each beaker is equal to the concentration of the solution that had been prepared in beaker A.

ii Calculate the number of moles of solute in each of the beakers I, II, III.
<u>Provide detailed calculations</u>.

ג. The students added different solutions to each of the beakers I, II, III.
To beaker I they added a certain volume of hydrochloric acid solution, $HC\ell_{(aq)}$, whose concentration was 0.2M, and stirred well. A reaction occurred.
When the reaction was complete, the pH was 7.

i Formulate the equation of the net reaction that occurred.

ii What volume of $HC\ell_{(aq)}$ had been added to beaker I?
<u>Provide detailed calculations</u>.

To beaker II the students added 150 ml of a sulfuric acid solution, $H_2SO_{4(aq)}$, with a concentration of 0.2M, and stirred well. A reaction occurred.

iii Determine whether, when the reaction was complete, the pH in beaker II was acidic, alkaline, or neutral.
<u>Provide detailed calculations or explain in words</u>.

ד. To beaker III the students added 80 ml of aluminum chloride solution, $A\ell C\ell_{3(aq)}$.
The solution turned a cloudy white.
The equation for the net reaction is shown below.

$$A\ell^{3+}_{(aq)} + 3OH^{-}_{(aq)} \longrightarrow A\ell(OH)_{3(s)}$$

All the reactants reacted completely.
Calculate the concentration of $A\ell C\ell_{3(aq)}$ solution that was added to beaker III.

/continued on page 16/

Structure and bonding, energy

14. This question discusses the substances carbon dioxide, $CO_{2(g)}$, and carbon disulfide, $CS_{2(\ell)}$.

א. i Explain why, at room temperature, carbon disulfide is a liquid but carbon dioxide is a gas.

Under certain conditions, carbon dioxide dissolves in carbon disulfide.

ii Explain why carbon dioxide, $CO_{2(g)}$, dissolves in carbon disulfide, $CS_{2(\ell)}$.

iii Formulate the equation for the dissolution of carbon dioxide in carbon disulfide.

ב. i Draw the electron dot diagram for a CO_2 molecule and the electron dot diagram for a CS_2 molecule.

ii The following table shows bond enthalpy values for two types of bonds that occur in molecules of CO_2 and of CS_2.

Match each value with the correct bond. List the <u>two</u> factors that cause the difference in bond enthalpy.

Bond enthalpy $\frac{kJ}{mol}$ (kjoule per mole)	**Bond**
803	
573	

ג. The enthalpy of evaporation of carbon disulfide is $27.6\frac{kJ}{mol}$.

i Formulate the equation for the reaction of carbon disulfide evaporation and list the value and sign of ΔH^0 for the reaction.

Equation (1) below describes the combustion reaction of liquid carbon disulfide, as well as the change in enthalpy associated with the reaction.

(1) $CS_{2(\ell)} + 3O_{2(g)} \longrightarrow CO_{2(g)} + 2SO_{2(g)}$ $\qquad \Delta H_1^0 = -1076.1\frac{kJ}{mol}$

Equation (2) below describes the combustion reaction of carbon disulfide gas.

(2) $CS_{2(g)} + 3O_{2(g)} \longrightarrow CO_{2(g)} + 2SO_{2(g)}$ $\qquad \Delta H_2^0 = ?$

ii Calculate the value of ΔH_2^0. <u>Provide detailed calculations</u>.

/continued on page 17/

ד. In each molecule of sulfur dioxide, SO_2 , the sulfur atom is bonded with two atoms of oxygen.

Let S-O denote each of these bonds.

Given: The bond enthalpy of O= O is $497\frac{kJ}{mol}$.

Calculate the enthalpy of the bond S-O in a molecule of SO_2 .

Use the data in the question and your answers to the previous items.

Provide detailed calculations.

Good Luck!

בהצלחה!