State of Israel
Ministry of Education
Exam Type: *Bagrut*
Exam Date: Summer 2019
Exam number: 037282
Attachment: Formulas and data for Chemistry
English Translation (3)

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תשע"ט, 2019
מספר השאלון: 037282
נספח: נוסחאות ונתונים בכימיה
תרגום לאנגלית (3)

Chemistry

כ י מ י ה

Instructions for examinees

א. Duration of the exam: Two hours

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

Part One	—	$33\frac{1}{3}$ points
Part Two	—	$33\frac{1}{3}$ points
Part Three	—	$33\frac{1}{3}$ points
Total	—	100 points

ג. Material that may be used during the exam:
(1) a calculator (graphing calculators are permitted)
(2) a Hebrew-foreign language/foreign language-Hebrew dictionary

ד. Special instructions: none

הוראות לנבחן

א. משך הבחינה: שעתיים.

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

פרק ראשון	—	$33\frac{1}{3}$ נקודות
פרק שני	—	$33\frac{1}{3}$ נקודות
פרק שלישי	—	$33\frac{1}{3}$ נקודות
סה"כ	—	100 נקודות

ג. חומר עזר מותר בשימוש:
(1) מחשבון (כולל מחשבון גרפי)
(2) מילון עברי-לועזי/לועזי-עברי

ד. הוראות מיוחדות: אין.

Write in the answer booklet only. Write the word "טיוטה" at the top of each draft page. If you write 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

This exam has three parts. Answer three questions, **one question from each part of the exam**.

Part One — Chemical Equilibrium and Entropy ($33\frac{1}{3}$ points)

Answer one question: Question 1 or Question 2.

Note: Make sure that all equations are balanced and that units are written correctly.

1. At the solar tower built at the Weizmann Institute, scientists researched conversion of sunlight into other forms of energy. In order to convert sunlight into heat energy, they set up many mirrors that concentrate the sunlight into a structure, and then conducted various reactions, such as Reaction (1), in this structure:

(1) $CO_{2(g)} + CH_{4(g)} \rightleftharpoons 2CO_{(g)} + 2H_{2(g)}$

The following table shows values of standard enthalpy of formation, ΔH_f^0 , for the reactants and products in Reaction (1).

Substance	Hydrogen $H_{2(g)}$	Carbon monoxide $CO_{(g)}$	Methane $CH_{4(g)}$	Carbon dioxide $CO_{2(g)}$
Standard enthalpy of formation, ΔH_f^0 $\left(\frac{kJ}{mol}\right)$	0	-110	-75	-394

א. i Calculate the change in enthalpy in Reaction (1), $\Delta H_{(1)}^0$.
Show detailed calculations.

ii During Reaction (1), the entropy of the system rises and the entropy of the environment decreases. Explain each of these two facts.

iii Reaction (1) is performed at a temperature of 1300K. Explain why this reaction is performed at a high temperature.

The mixture of products of Reaction (1) has a high energy content. The mixture is transferred to storage or to a device with a fixed volume and a reverse reaction is performed, Reaction (2):

(2) $2CO_{(g)} + 2H_{2(g)} \rightleftharpoons CO_{2(g)} + CH_{4(g)} \qquad \Delta H_{(2)}^0 < 0$

The energy released is used to create steam, and the steam can be used to produce electricity.

ב. i At what temperature will Reaction (2) be more highly favored: 298K or 1000K? Explain.

ii Suggest a method to experimentally test in a lab whether the Reaction (2) system is in equilibrium at the temperature that you chose in Sub-item ב.i.
Explain the method you proposed.

/Continued on page 3/

ג. Three experiments, I, II, and III, were conducted.
In each experiment, $CO_{(g)}$ and $H_{2(g)}$ were put in an empty container, and then the container was closed.
The initial concentrations of the two gases in each of the containers were identical.
In each experiment, Reaction (2) was performed at a different temperature.
The temperatures at which the experiments were run:

	Experiment I	Experiment II	Experiment III
Temperature (K)	298	500	1100

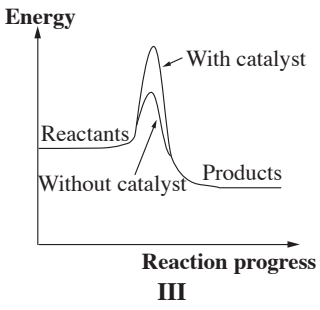
In each container, the system reached equilibrium.
Determine in which of the three experiments the system reached equilibrium in the shortest time.
Explain, using collision theory.

The mixture of products obtained in Reaction (1) can be used to manufacture various compounds. One of these compounds is methanal, $CH_2O_{(g)}$, which serves as a raw material in the manufacture of plastic products.
Methanal is formed according to Reaction (3):

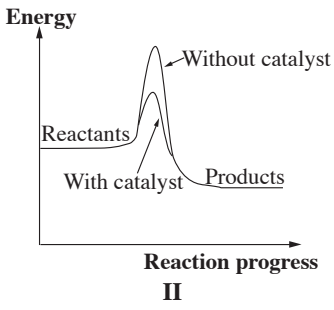
(3) $CO_{(g)} + H_{2(g)} \rightleftharpoons CH_2O_{(g)} \qquad \Delta H^0_{(3)} < 0$

ד. For Reaction (3), the value of the equilibrium constant at 500K is $K_c = 2.8 \cdot 10^{-4}$.
An experiment was conducted: 0.02mol $CO_{(g)}$, 0.02mol $H_{2(g)}$, and 0.012mol $CH_2O_{(g)}$ were added to a 1 liter closed container.
Determine whether the rate of the forward reaction, until the system reaches equilibrium, is higher than or lower than the rate of the reverse reaction. Show detailed calculations and explain.

ה. In industry, Reaction (3) is performed in the presence of an appropriate catalyst.
Which of the following graphs I-III correctly describes the change in energy during Reaction (3), with and without a catalyst?
Explain why you ruled out the other two graphs.



III



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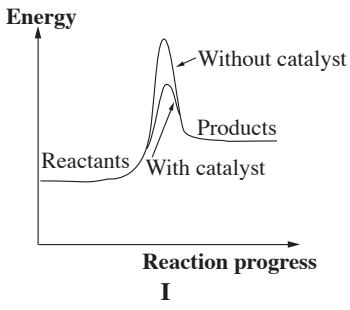

I

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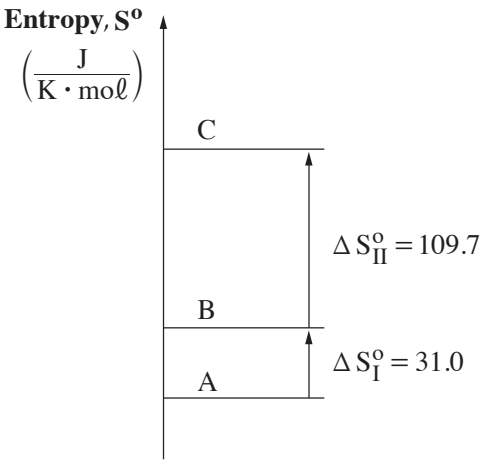
2. Wine is an aqueous solution containing, among other things, ethanol, C_2H_5OH .

א. The following diagram shows changes in the standard molar entropy, ΔS^0 , of ethanol in different states of matter.



i The letters A, B, C represent ethanol in different states of matter (solid, liquid, gas). Determine which state of matter is represented by <u>each</u> of the letters A, B, and C.

ii Explain why the value of ΔS^0_I is smaller than the value of ΔS^0_{II} .

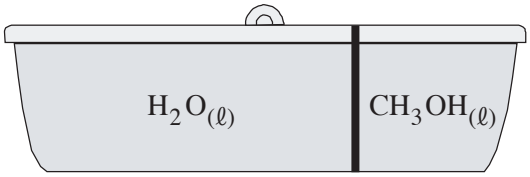
iii Calculate the change in system entropy at the transition of ethanol from the gaseous to the solid state.
<u>Show detailed calculations, and explain the sign</u> (plus or minus) of the value that you calculated.

/Continued on page 5/

ב. In the summer of 2018 it was discovered that a number of retailers had been selling wine that contained methanol, CH_3OH.

Methanol is a toxic substance and drinking it can cause blindness and even death.

An experiment was conducted in a lab: The experimenter took a closed container with an internal divider and filled one side with methanol and the other side with water, as shown in the figure below.



The divider was removed and the liquids were mixed.

i When methanol dissolves in water, the entropy of the system increases.

Read Statements a and b , below.

Determine which statement is correct and explain why you ruled out the other statement.

a. When completely dissolved, the total number of moles of particles in the container was greater than the total number of moles of particles when mixing began.

b When completely dissolved, the dispersion of particles was greater than their dispersion when mixing began.

ii Dissolving methanol in water is an exothermic reaction. Determine whether this process is spontaneous at ambient conditions. Explain.

/Continued on page 6/

Under suitable conditions, methanol and ethanol will burn. Below is the combustion reaction of both these alcohols:

(1) $CH_3OH_{(\ell)} + 1.5O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(\ell)}$ $\qquad \Delta S^o_{(1)} = -80.5\frac{J}{K}$

(2) $C_2H_5OH_{(\ell)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 3H_2O_{(\ell)}$ $\qquad \Delta H^o_{(2)} = -1369kJ$

The following table shows the standard molar entropy, S^o, of some of the substances in Reactions (1) and (2):

Substance	$CO_{2(g)}$	$O_{2(g)}$	$C_2H_5OH_{(\ell)}$	$CH_3OH_{(\ell)}$
Standard molar entropy, S^o $\left(\frac{J}{K \cdot mo\ell}\right)$	214	205	161	127

ג. Calculate the standard molar entropy, S^o, of $H_2O_{(\ell)}$. Show detailed calculations.

ד. i Determine whether the entropy of the system increases or decreases during Reaction (2). Explain without calculating.

ii Calculate the change in the entropy of the system in Reaction (2). Show detailed calculations.

iii Determine whether Reaction (2) is spontaneous at a temperature of 303K. Show detailed calculations and explain.

/Continued on page 7/

Part Two — Polymers ($33\frac{1}{3}$ points)

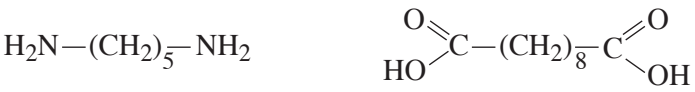
Answer one question: Question 3 or Question 4.

3. This question discusses a few polymers that are used to manufacture fibers.

Below are the structural formulas of the monomers from which polymers (1)-(4) are obtained:

Polymer (1) — nylon 5,10 — used to manufacture fiber for women's panty-hose (tights).

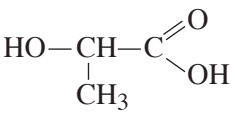
It is obtained from the monomers:



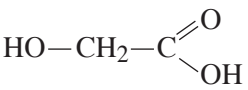
Polymer (2) — polyethylene terephthalate (PET) — used to manufacture soft-drink bottles.

It is obtained from the monomers:

Below are the structural formulas of the monomers that can be used to obtain Polymers (3) and (4):



Lactic acid



Glycolic acid

Polymer (3) — polyglycolic acid (PGA) — used to manufacture woven fabric.

Copolymer (4) — PLGA — a random copolymer that is obtained from lactic acid and glycolic acid. This polymer is used to manufacture surgical suture thread.

א. i Determine which polymerization method was used to prepare <u>each</u> of the four polymers (1)-(4) — condensation or addition.

ii Write out the structural formula of the repeating unit in <u>each</u> of the three polymers (1)-(3).

/Continued on page 8/

ב. i The percent crystallinity of Polymer (2) is higher than the percent crystallinity of Polymer (1). Explain why.

ii Polymers (1) and (2) can be used to manufacture fibers. List two reasons for this for each polymer.

ג. Soft drink bottles made of Polymer (2), PET, can be recycled.
The bottles are washed and shredded and the polymer is processed by stretching the fibers so they can be used to manufacture fabrics such as fleece [פליז].

i Stretching Polymer (2) is an important step in manufacturing fleece fibers. Explain why.

ii Determine whether Polymer (2) is a thermoplastic, elastomeric, or thermoset polymer. Explain your answer.

ד. i Write out the structural formula of a representative section of the random Copolymer (4).

ii The melting point T_m of Copolymer (4) is lower than the melting point of Polymer (3). Explain why.

iii Suture thread made of Copolymer (4) disintegrates in the body after surgery over a few weeks because the copolymer is hydrolyzed by the body fluids (which are mostly water).
The products of this hydrolysis are naturally present in the human body.
Write out the structural formulas of the products of full hydrolysis of Copolymer (4).

/Continued on page 9/

4. The following table shows data for four polymers that have similar average degrees of polymerization.

	Polymer	**Structural formula of repeating unit**	**Glass-transition temperature T_g (^oC)**	**Melting point T_m (^oC)**	**Some uses of the polymer**
(1)	Polyvinyl chloride (PVC)	$-CH_2-\underset{\displaystyle C\ell}{\underset{\vert}{CH}}-$	80	265	– Flooring – Electrical wire insulation
(2)	Polyvinyl fluoride (PVF)	$-CH_2-\underset{\displaystyle F}{\underset{\vert}{CH}}-$	40	190	– Raincoats – Solar panels
(3)	Teflon	$-CF_2-CF_2-$	125	330	– Utensil coatings – Insulators in the electrical industry
(4)	Polypropylene (PP)	$-CH_2-\underset{\displaystyle CH_3}{\underset{\vert}{CH}}-$	– 18	165	– Sheets for packaging – Machine parts

א. The four polymers (1)-(4) are obtained using the same polymerization method.

Determine which method it is: is it addition or condensation? Explain.

ב. Two samples, I and II, of Polymer (1) were prepared in a lab from equal quantities of monomer.

Sample I was prepared with 0.2 gram of initiator, and Sample II was prepared with 2 grams of the same initiator.

i The average degree of polymerization of the polymer in Sample I is greater than the average degree of polymerization of the polymer in Sample II. Explain why.

ii The polymerization process of Sample II is faster than the polymerization process of Sample I. Explain why.

ג. i Determine in which polymer, (1) or (2), the chains form random coils more readily. Explain.

ii Explain why the T_m of Polymer (2) is higher than the T_m of Polymer (4).

/Continued on page 10/

ד. During polymerization of Polymer (4), its average molar mass, $\overline{M}$, can be controlled. This makes it possible to adapt the properties of a polymer to the requirements of specific products.

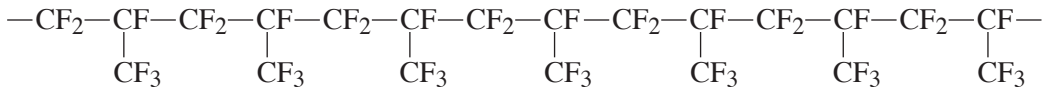
The higher the average molar mass of Polymer (4), the higher its melting point, T_m .

Explain why.

ה. A random copolymer can be obtained by polymerization of the Polymer (3) monomer and the monomer $CF_2 = CF - CF_3$.

Determine which of the three structural formulas, I-III, below, is the correct formula of a representative segment of the random copolymer.

I



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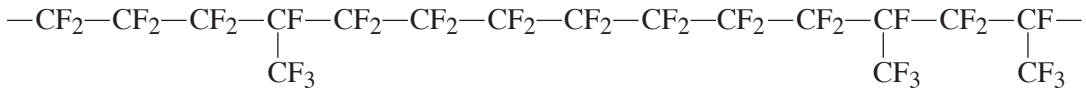

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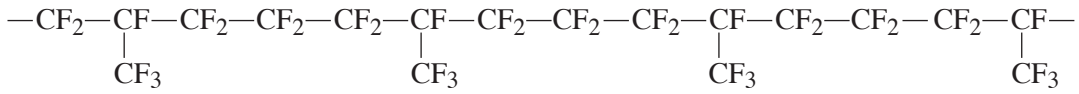

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Part Three —

Physical Chemistry: From Nano to Microelectronics ($33\frac{1}{3}$ points)

Answer one question: Question 5 or Question 6.

Note: Make sure that equations are balanced and that units are written correctly.

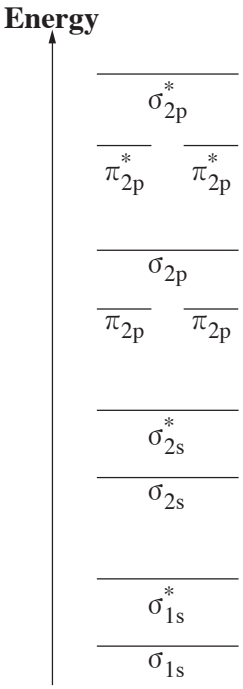
5. The air in the atmosphere of Earth is a mixture of gases and its chief component is nitrogen, $N_{2(g)}$ (about 80%). The air also contains other gases, one of which is hydrogen, $H_{2(g)}$, (about 0.00005%).

א. i Draw a Lewis electron dot diagram for the ion H_2^-.

ii Determine whether the ion H_2^- is more stable or less stable than the H_2 molecule. Explain.

ב. i Below is an energy level diagram for a diatomic molecule of an element located in the second row of the periodic table.

Copy the diagram to your notebook and mark on it the arrows that represent the electrons populating the orbitals in an excited nitrogen molecule, N_2^*.



ii In the diagram you drew for Sub-item ב.i, mark the HOMO level and the LUMO level.

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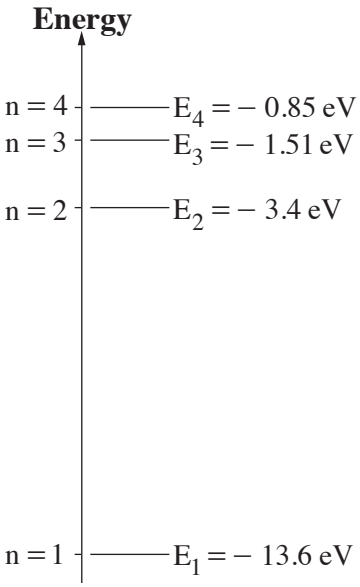
ג. The diagram below shows the four first energy levels (E_1 - E_4) of a hydrogen atom.



i Calculate the energy of transition from energy level E_1 to energy level E_2, in Joules (J). Show detailed calculations.

ii Determine whether red peppers absorb radiation that is emitted in the energy transition $E_3 \rightarrow E_2$. Show detailed calculations and explain.

ד. Silicon, $Si_{(s)}$, is a semiconductor.

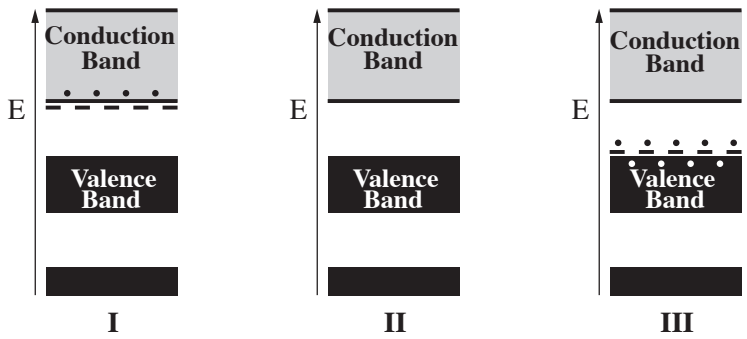
i Explain why the electrical conductivity of a pure silicon crystal is low at room temperature and high at high temperatures.

ii Below are three energy diagrams I, II, and III. Match a description from the three following descriptions with each of the diagrams:

— pure silicon crystal

— n-type semiconductor structure

— p-type semiconductor structure



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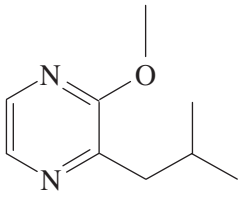
6. This question is about beverages made of coffee beans.

א. Green coffee beans contain a substance called IBMP.

Below is the abbreviated structural formula of a molecule of this substance.

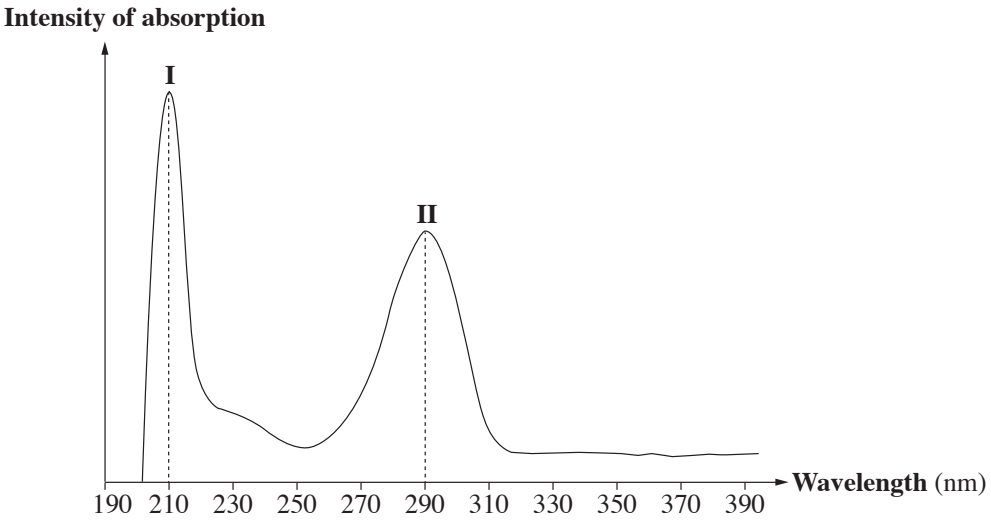


i Copy the formula to your notebook and circle the chromophore.

ii The green color of coffee beans is not caused by the substance IBMP. Explain why.

To improve their quality, some types of coffee have vitamins such as B vitamins are added to them.

Below is a section of the absorption spectrum for vitamin B6.



ב. There are two absorption maxima in the given absorption spectrum.

In the wavelength range of 390nm to 780nm (which is not shown in the given spectrum) there is no absorbance of significant intensity.

i Determine in which absorbance, I or II, the photonic energy of the radiation is higher. Explain but do not calculate.

ii Based on your answer to Sub-item ב.i , calculate the higher photonic energy. Show detailed calculations.

/Continued on page 14/

iii Calculate the radiation frequency for the photon whose energy you calculated in Sub-item ב.ii . Show detailed calculations.

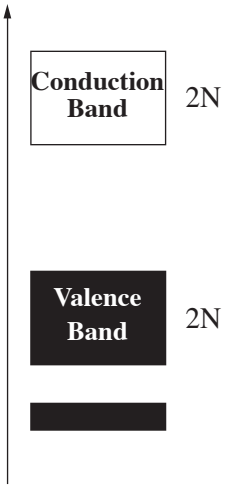
iv Determine whether the radiation frequency which you calculated in Sub-item ב.iii is higher or lower than the radiation frequency of green light.
Explain but do not calculate.

ג. Use a segment of the absorption spectrum of vitamin B6 to determine whether vitamin B6 is a colored or colorless substance. Explain your answer.

ד. Doctors advise against drinking large amounts of coffee.
One reason is that coffee inhibits absorption of calcium ions, Ca^{2+} , in the body. One of the processes that the body needs calcium ions for is bone building.

i Write out the electron configuration of the calcium ion.

ii Below is a diagram that shows the final energy level of a solid.



This diagram does not describe the final energy level of a calcium crystal, $Ca_{(s)}$, that contains N atoms. Explain why.

Good Luck!

בהצלחה!