State of Israel
Ministry of Education
Exam Type: *Bagrut*
Exam Date: Summer 2017
Exam number: 037282
Attachment: Formulas and data for Chemistry
English Translation (3)

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תשע"ז, 2017
מספר השאלון: 037282
נספח: נוסחאות ונתונים בכימיה
תרגום לאנגלית (3)

Chemistry

Reform for Meaningful Learning Program

כימיה

על פי תכנית הרפורמה ללמידה משמעותית

Instructions for examinees

א. Duration of the exam: Two hours

ב. Exam structure and breakdown of points:
This test 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 only in the exam booklet. Write whatever you wish to write as a draft (notes, calculations, etc.) on separate pages in the booklet and write "טיוטה" at the top of each of these pages. If you write any sort of notes or calculations outside the exam booklet, your exam may be disqualified!

כתוב במחברת הבחינה בלבד, בעמודים נפרדים, כל מה שברצונך לכתוב כטיוטה (ראשי פרקים, חישובים וכדומה). רשום "טיוטה" בראש כל עמוד טיוטה. רישום טיוטות כלשהן על דפים שמחוץ למחברת הבחינה עלול לגרום לפסילת הבחינה!

Good Luck!

בהצלחה!

Questions

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

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

Answer <u>one</u> of the questions 1-2.

<u>Note</u>: Make sure that all equations are balanced and that units are written correctly.

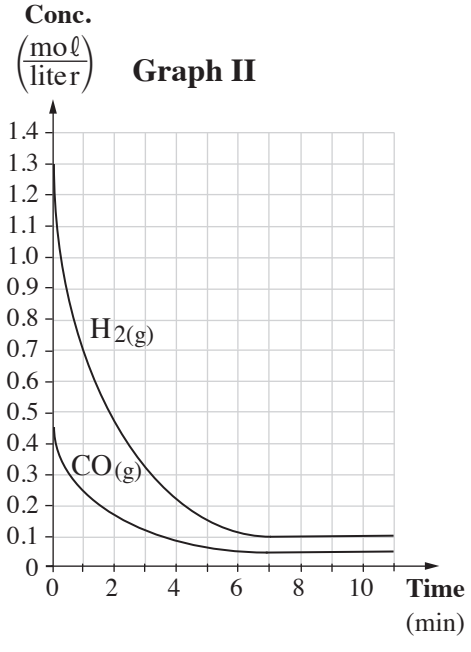
1. This question concerns Reaction (1), which is used in the chemical industry to remove carbon monoxide, $CO_{(g)}$, from gaseous mixtures.

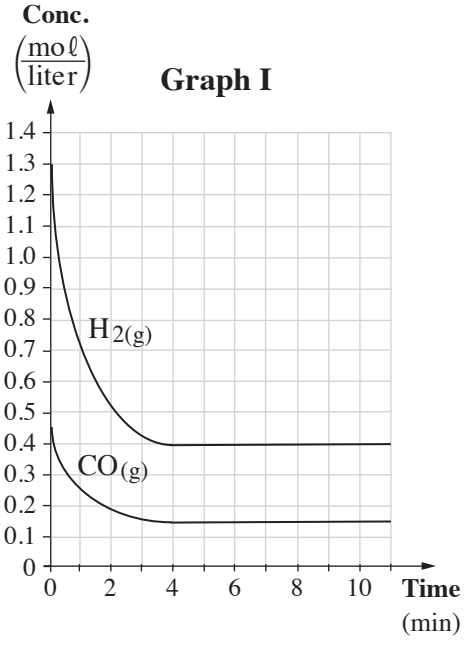
(1) $CO_{(g)} + 3H_{2(g)} \rightleftarrows CH_{4(g)} + H_2O_{(g)} \quad \Delta H_1^0 = -206\text{kJ}$

In a laboratory, Reaction (1) was carried out in two closed containers, A and B. Each container had a volume of 1 liter.

0.45 moles of carbon monoxide, $CO_{(g)}$, were put into each of the empty containers, along with 1.3 moles of hydrogen, $H_{2(g)}$. Each container was kept at a constant temperature. The temperature inside Container A was different from the temperature inside Container B.

Graphs I and II below describe the changes in the concentrations of the reactants in Containers A and B over time.





/Continued on page 3/

א. i Did the pressure inside each container increase, decrease or remain the same from the start of the reaction through the moment that equilibrium was reached? Explain each of your answers.

ii Over the course of Reaction (1), did the entropy of the system increase or decrease?
Explain what happened at the microscopic level.

iii Over the course of Reaction (1), did the entropy of the environment increase or decrease? Explain your answer.

iv Under certain conditions, Reaction (1) does not proceed spontaneously. Explain this fact.

ב. For the system described in Graph I:

i Calculate the concentration of methane, $CH_{4(g)}$, and the concentration of water vapor, $H_2O_{(g)}$, at the equilibrium point. Show detailed calculations.

ii Write out an expression of the equilibrium constant for Reaction (1) and calculate the value of that constant. Show detailed calculations.

ג. i The equilibrium constant of the system in Container A is greater than the equilibrium constant of the system in Container B. Which graph, I or II, describes the system in Container A? Explain.

ii In which container, A or B, was the temperature higher?

ד. At the 12th minute, the temperature in Container B was raised. Some time later, the system reached a new equilibrium point. Is the concentration of $CH_{4(g)}$ in Container B at this new equilibrium point greater than, less than or the same as it was at the earlier equilibrium point? Explain your answer.

/Continued on page 4/

2. Fuel cells in which hydrogen, $H_{2(g)}$, reacts with oxygen, $O_{2(g)}$, can serve as an alternative energy source, for example for powering motor vehicles.
In some industrial settings, methanol, $CH_3OH_{(g)}$, is used as a raw material for the production of $H_{2(g)}$.
In the presence of an appropriate catalyst, methanol, $CH_3OH_{(g)}$ reacts with $O_{2(g)}$ as shown in Reaction (1).

(1) $CH_3OH_{(g)} + \frac{1}{2}O_{2(g)} \rightarrow 2H_{2(g)} + CO_{2(g)} \qquad \Delta H_1^0 < 0$

א. Reaction (1) proceeds spontaneously under standard conditions at any temperature. Explain why.

ב. Under the right conditions, $CH_3OH_{(g)}$ reacts with steam, $H_2O_{(g)}$, as shown in Reaction (2).

(2) $CH_3OH_{(g)} + H_2O_{(g)} \rightarrow 3H_{2(g)} + CO_{2(g)}$

i The standard molar entropy values, S^0, of the reactants and products of Reaction (2) are presented in the table below.

Substance	$CO_{2(g)}$	$H_{2(g)}$	$H_2O_{(g)}$	$CH_3OH_{(g)}$
Standard molar entropy $S^0(\frac{J}{K \cdot mol})$	213.6	130.6	188.7	239.9

Calculate the change in the entropy of the system, ΔS^0_{system}, for Reaction (2).
Show detailed calculations.

ii At a temperature of 298 K, the change in the entropy of the universe is as follows: $\Delta S^0_{universe} = +10.4\frac{J}{K}$.
Calculate the change in enthalpy, ΔH_2^0, for Reaction (2).
Show detailed calculations.

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Reaction (3) is also used to produce $H_{2(g)}$ in industrial settings.

In Reaction (3), carbon monoxide, $CO_{(g)}$ reacts with steam, $H_2O_{(g)}$.

(3) $CO_{(g)} + H_2O_{(g)} \rightleftarrows H_{2(g)} + CO_{2(g)} \qquad \Delta H_3^0 < 0$

ג. i Three values for the change in the entropy of a system, ΔS^0_{system}, are shown below:

$-138\frac{J}{K} \qquad -42.4\frac{J}{K} \qquad +214.8\frac{J}{K}$

Which of these values is the correct ΔS^0_{system} value for Reaction (3)? Explain.

ii Values for the change in entropy of the universe, $\Delta S^0_{universe}$, for Reaction (3) at two different temperatures are presented in the table below.

Temperature (K)	500	1100
$\Delta S^0_{universe}$ $(\frac{J}{K})$	+ 40	– 4.9

Refer to the change in the entropy of the system, ΔS^0_{system}, and the change in the entropy of the environment, $\Delta S^0_{environment}$, and explain why there is an increase in the entropy of the universe when the forward reaction proceeds at 500 K, whereas at 1100 K the entropy of the universe decreases.

(Note: This question continues on the next page.)

/Continued on page 6/

7. Reaction (3) was carried out in three closed containers: I, II and III.
The numbers of moles of each type of gas that were put into each container are listed in the table below.

Container	**Volume of the container (liters)**	**No. of moles of gas put into the container**			
		$CO_{(g)}$	$H_2O_{(g)}$	$H_{2(g)}$	$CO_{2(g)}$
I	1.0	0.4	0.4	0	0
II	1.0	0.8	0.4	0	0
III	1.0	0	0	0.2	0.2

The three containers were kept at the same temperature.
The statements shown below, i and ii, refer to the system in each of the containers: I, II and III.
Explain why each of these statements (i and ii) is incorrect.

i The K_c value for the system in Container II is greater than the K_c value for the system in Container I, because the concentration of $H_{2(g)}$ at equilibrium is greater in Container II.

ii The system in Container III does not reach equilibrium, because the reactants $CO_{(g)}$ and $H_2O_{(g)}$ were not put into that container.

/Continued on page 7/

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

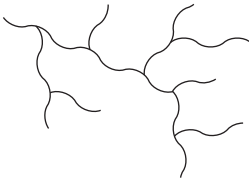
Answer one question: Question 3 or Question 4.

3. Polyethylene, $+CH_2-CH_2+_n$, is a common polymer that is used to produce packaging material, storage containers, household utensils, bottles and irrigation pipes, among other things.
Different types of polyethylene, such as low-density polyethylene (LDPE) and high-density polyethylene (HDPE), are produced under different polymerization conditions.

א. Schematic descriptions of two polyethylene chains, I and II, are shown below.

II

I



Which chain is a chain of low-density polyetheylene: I or II? Explain.

ב. Tg and Tm values of the polymers LDPE and HDPE are presented in the table below.

Polymer	**Glass transition temperature** Tg (°C)	**Melting point** Tm (°C)
LDPE	– 80	110
HDPE	– 50	?

i The polymer HDPE has a low Tg value. Explain this fact.

ii Explain why the Tg value of the polymer LDPE is lower than the Tg value of the polymer HDPE.

iii Is the Tm value of the polymer HDPE higher or lower than 110°C? Explain.

/Continued on page 8/

Two of the properties required of a polymer to be used in food packaging are listed below:

– It should have good impermeability to gases, especially oxygen, $O_{2(g)}$, and carbon dioxide, $CO_{2(g)}$.
– It should be impermeable to humidity, $H_2O_{(g)}$.

ג. Gases penetrate the amorphous regions of the polymer, but not the crystalline regions. Explain why. In your answer, refer to both the amorphous and the crystalline regions.

ד. Polyvinyl alcohol (PVA), $+CH_2-CH(OH)+_n$, is the polymer that is most impermeable to $O_{2(g)}$ and $CO_{2(g)}$.
Name <u>one</u> disadvantage to using the polymer PVA in food packaging.
<u>Explain your answer</u>.

ה. EVOH is a random copolymer that is made up of units of polyethylene and units of PVA.
The copolymer EVOH has a high percentage of crystallinity and good impermeability to gases.

i Write a structural formula for a 12-carbon-atom section of the copolymer EVOH chain.
ii Explain why the copolymer EVOH has a high percentage of crystallinity.
iii The greater the percentage of PVA units in copolymer EVOH chains, the greater the Tg value of the copolymer. Explain why.

/Continued on page 9/

4. This question concerns some polymers that are used to produce fibers.

א. Of the properties (1)-(6) listed below, choose <u>three</u> that are characteristic of polymers used to produce fibers.

(1) Strong intermolecular forces

(2) Covalent cross-bonding

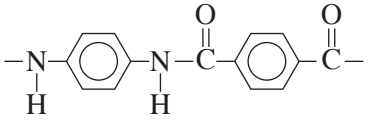
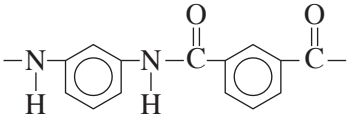
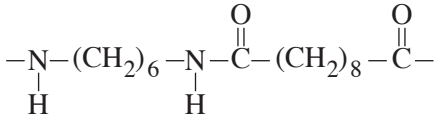
(3) Long chains without side groups

(4) Glass-transition temperature, Tg, that is lower than room temperature

(5) An amorphous structure

(6) The presence of rigid sections in the backbone of the chain

Information about three polymers used to produce fibers is presented in the table below.

Polymer	**Skeletal Formula of the Repeating Unit**	**Melting point** Tm (°C)	**One Use of Fibers Made of this Polymer**
Kevlar		500	Lift cables for cable-cars
Nomex		375	Protective clothing for firefighters
Nylon 6,10		210	Bristles for brushes

ב. i Which method – condensation or addition – was used to make <u>each</u> of the polymers listed in the table? <u>Explain</u>.

ii Write the skeletal formulas [ייצוג מקוצר] of the monomers used to make each of the polymers listed in the table.

/Continued on page 10/

ג. i Explain why the Tm value of Kevlar is higher than the Tm value of Nylon 6,10.

ii Explain why the Tm value of Nomex is lower than the Tm value of Kevlar.

iii No Tg value was measured for the polymer Kevlar. Explain why.

ד. Formulas of two substances, I and II, are shown below:

I $CH_2 = CH - CN$

II $CH_3 - CH_2 - NH_2$

In a laboratory, polymerization was carried out in two containers, A and B, in order to obtain Nylon 6, 10.

The same amount of monomers was put into each of the two containers. An additional substance was added to Container A and that substance reacted in the container.

i Was that additional substance Substance I or Substance II? Explain your answer.

ii Are the polymer chains that were obtained in Container A longer, shorter or the same length as the polymer chains obtained in Container B? Explain your answer.

iii Is the repeating unit of the polymer that was obtained in Container A the same as or different from the repeating unit of the polymer obtained in Container B? Explain your answer.

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Part Three

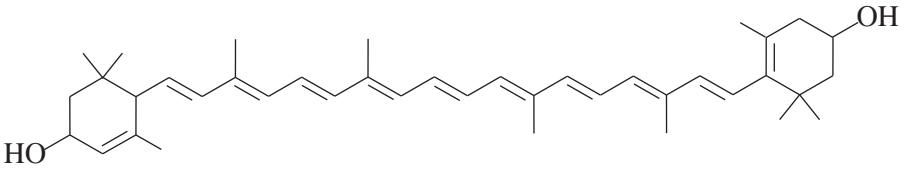
Physical Chemistry — From the Nano Level to Microelectronics ($33\frac{1}{3}$ points)

Answer one question: Question 5 or Question 6.

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

5. This question concerns processes that occur in fruits and vegetables.

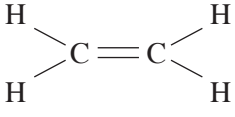
א. As a melon ripens, it produces the pigment lutein, which gives the fruit its yellow color. The skeletal formula of a molecule of lutein is shown below.



Radiation of which wavelength will be absorbed by the lutein molecule: 450 nm or 580 nm? Explain your answer.

ב. The gas ethylene is produced in plants and causes the ripening of many fruits and vegetables.

The structural formula of a molecule of ethylene is shown below.



i How many σ bonds and how many π bonds are there in one molecule of ethylene?

ii Ethylene absorbs radiation at a wavelength of 171 nm. Calculate the difference in energy, in units of J, between the HOMO orbital and the LUMO orbital of a molecule of ethylene. Show detailed calculations.

iii Explain why ethylene absorbs radiation at a shorter wavelength than the wavelength absorbed by lutein.

/Continued on page 12/

ג. To accelerate the ripening of various fruits and vegetables after they have been harvested, a mixture of gases is applied in the area in which the produce is stored. This mixture is mostly nitrogen gas, $N_{2(g)}$, with about 5% ethylene gas.

i Copy the molecular orbital diagram for a molecule of nitrogen, $N_{2(g)}$, from the formula sheet into your answer booklet and populate the orbitals:
– for two nitrogen atoms
– for a molecule of nitrogen

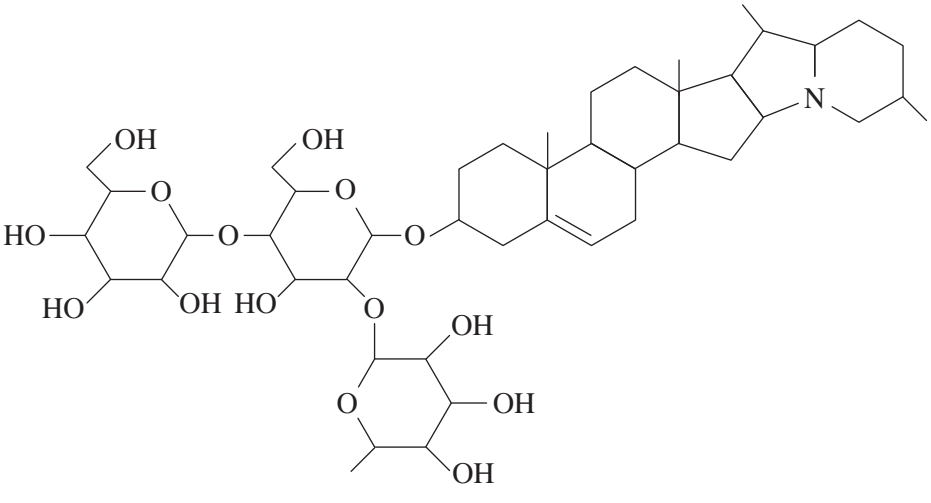
ii Label the HOMO and LUMO orbitals in the electron configuration of a nitrogen molecule in its ground state [מצב אלקטרוני יסודי].

iii Calculate the bond order of a nitrogen molecule.
Show detailed calculations.

ד. When potatoes are stored in the light, green spots appear on their skin and they become bitter.

The bitter substance is called solanine. Solanine is poisonous and must not be eaten.

The skeletal formula of solanine is shown below.



Is the green that appears on potato skins the color of the solanine?
Explain your answer.

(Note: This question continues on the next page.)

/Continued on page 13/

ה. In order to speed up the ripening of harvested strawberries, the berries are placed under blue LED (light-emitting diode) bulbs.

Determine whether each of the statements below, a, b and c, is correct or incorrect.

a The blue LED emits light at a wavelength of 470 nm.

b The light emitted by the blue LED corresponds with the difference in energy between the conduction band [פס ההולכה] of an n-type semiconductor and the valence band [פס הערכיות] of a p-type semiconductor.

c When the blue LED emits light, the p-type semiconductor is connected to the negative terminal of the battery and the n-type semiconductor is connected to the positive terminal.

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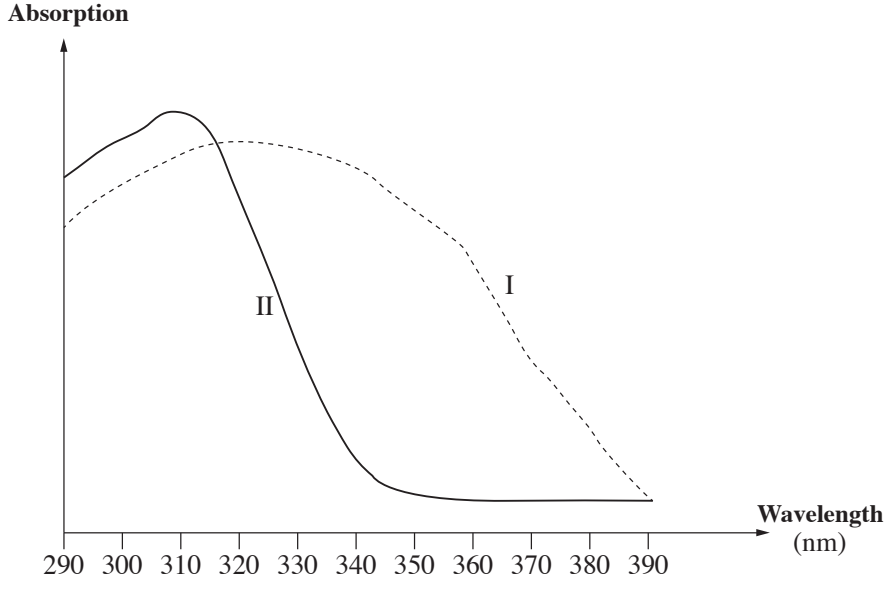
6. Preparations that are used to protect the skin against ultraviolet (UV) radiation from the sun contain substances that filter radiation [מסנני קרינה].
Photons of UV radiation have high levels of energy that cause damage to the skin, for example, sunburn.
Radiation filters absorb ultra-violet radiation at two wavelength ranges: UVA within the range of 320-390 nm and UVB within the range of 290-320 nm.
This absorption of radiation reduces the damage done to skin.

א. Which type of radiation causes more damage to the skin: UVA or UVB?
Explain your answer.

The absorption spectra of two commercially-produced radiation filters (I and II) are shown in the graph below.



ב. i Filter I provides better protection from the sun.
Explain this fact.

ii Based on the data presented in the graph, the color of each radiation filter cannot be determined.
Explain why.

/Continued on page 15/

ג. One method of artificial tanning that does not involve the sun is the ingestion of capsules of the pigment canthaxanthin. Canthaxanthin molecules accumulate in the fat under the skin and give the skin a brownish color. Canthaxanthin absorbs radiation at a wavelength of 460 nm. What color is canthaxanthin?
Explain your answer.

Another method of artificial tanning is to tan under lamps that emit UV radiation.

ד. In the past, mercury lamps were sometimes used for tanning. Wavelengths of ultra-violet radiation emitted by mercury lamps used for tanning are listed here: 302 nm, 312 nm, 313 nm, 334 nm, 365 nm.

i Calculate the frequency of the radiation emitted at a wavelength of 312 nm. Show detailed calculations.

ii Explain why the emission spectrum of mercury lamps is a line spectrum and not a continuous spectrum.

ה. Today, people prefer to use a range of LED (light-emitting diode) bulbs for artificial tanning. These bulbs emit radiation at a variety of wavelengths, including: 365 nm, 385 nm, 395 nm and 405 nm.

i Name one advantage of tanning under LED bulbs over tanning under mercury lamps.

ii Is the difference in energy between the conduction and valence bands of LED bulbs that emit ultra-violet radiation greater than the difference in energy between the conduction and valence bands of LED bulbs that emit radiation within the visible range?
Explain your answer.

Good Luck!

בהצלחה!