State of Israel
Ministry of Education
Exam Type: *Bagrut*
Exam Date: Summer 2018
Exam number: 037282
Attachment: Formulas and data for Chemistry
English Translation (3)

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תשע"ח, 2018
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 only in the answer booklet. Write all draft material (notes, calculations, etc.) on separate pages in the answer booklet and write "טיוטה" at the top of each of these pages. If you write any sort of notes or calculations outside the answer 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 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. The combustion of fuel makes the temperature in a car engine high. As a result nitrogen and oxygen in the air react and form several compounds; one of them is nitrogen dioxide, $NO_{2(g)}$, which is a brown gas.

When $NO_{2(g)}$ is introduced into an empty container, Reaction (1) takes place and produces the colorless gas dinitrogen tetroxide, $N_2O_{4(g)}$.

(1) $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)} \qquad \Delta H^0_{(1)} < 0$

א. How can one see that Reaction (1) is taking place in the container?

ב. i Determine whether the entropy of the system increases or decreases during Reaction (1). Explain.

ii Determine whether the entropy of the surroundings increases or decreases during Reaction (1).

iii Reaction (1) is spontaneous at a temperature of 298K.
Determine whether the change in entropy of the surroundings at a temperature of 298K is greater or smaller than the change in system entropy. Explain.

A lab ran Reaction (1) in two closed containers, I and II. The volume of each container was 1 liter.

The same number of moles of $NO_{2(g)}$ was put in each of the empty containers, and the containers were sealed.

Container I was kept at a temperature of 298K. Container II was kept at a temperature of 500K.

Reaction (1) took place in both containers and both systems reached equilibrium.

ג. Determine which container, I or II, reached equilibrium in a shorter space of time. Explain using collision theory.

/Continued on page 3/

ד. i The values of the equilibrium constants, K_c, for the systems in the two containers I and II, are 0.025 and 170. Match each system (in Containers I and II) with its K_c. Explain.

ii Determine whether the concentration of $N_2O_{4(g)}$ in Container II, at equilibrium, is greater than, smaller than, or equal to the concentration of $N_2O_{4(g)}$ in Container I at equilibrium. Explain.

iii When the system in Container I reached equilibrium, there were 0.03 moles of $NO_{2(g)}$ in the container.

Write the expression for the equilibrium constant, K_c.

Calculate the concentration of $N_2O_{4(g)}$ in Container I at equilibrium.

Show detailed calculations.

ה. When the system in Container I reached equilibrium, a little $N_2O_{4(g)}$ was added to the container and the equilibrium was disturbed. After a certain amount of time the system reached a new equilibrium.

Determine whether the concentration of $NO_{2(g)}$ under the new equilibrium is greater than, smaller than, or equal to the concentration of $NO_{2(g)}$under the previous equilibrium. Explain.

/Continued on page 4/

2. Ethanal, $CH_3CHO_{(\ell)}$, is a flammable substance. One of its uses is in manufacturing perfumes. Below is the combustion reaction of gaseous ethanal, $CH_3CHO_{(g)}$.

(1) $2CH_3CHO_{(g)} + 5O_{2(g)} \longrightarrow 4CO_{2(g)} + 4H_2O_{(g)}$ $\qquad \Delta S^0_{\text{System (1)}} = 59\frac{J}{K}$

The following table shows thermodynamic data for the reactants and products of Reaction (1).

Substance formula	$H_2O_{(g)}$	$CO_{2(g)}$	$O_{2(g)}$	$CH_3CHO_{(g)}$
Standard molar entropy, $\mathbf{S^0}$ $\left(\frac{J}{K \cdot mol}\right)$	189	214	205	X
Standard enthalpy of formation, $\mathbf{\Delta H_f^0}$ $\left(\frac{kJ}{mol}\right)$	− 242	− 394	—	− 166

א. i Calculate the standard molar entropy of $CH_3CHO_{(g)}$ (the value of X in the table). Show detailed calculations.

ii Calculate the change in enthalpy in Reaction (1), $\Delta H^0_{(1)}$. Show detailed calculations.

ב. i The entropy of the surroundings increases during the reaction. Explain why this happens.

ii The entropy of the system increases during the reaction. Explain why this happens.

iii Determine whether Reaction (1) is spontaneous at room temperature. Explain.

ג. Reaction (2) describes phase transition for ethanal.

(2) $CH_3CHO_{(g)} \longrightarrow CH_3CHO_{(\ell)}$ $\qquad \Delta H^0_{(2)} < 0$

i Determine whether the standard molar entropy, S^0, of $CH_3CHO_{(\ell)}$ is higher or lower than the S^0 of $CH_3CHO_{(g)}$. Explain.

ii Determine whether Reaction (2) is spontaneous at all temperatures. Explain.

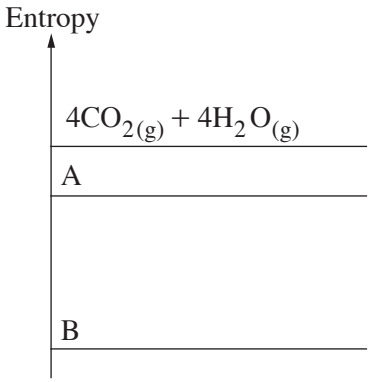
/Continued on page 5/

7. Reaction (3), below, represents the combustion reaction of liquid ethanal, $CH_3CHO_{(\ell)}$.

(3) $2CH_3CHO_{(\ell)} + 5O_{2(g)} \longrightarrow 4CO_{2(g)} + 4H_2O_{(g)} \qquad \Delta H^0_{(3)} = -2,160\,kJ$

i Calculate the change in entropy in the surroundings for Reaction (3) at a temperature of 280K.

ii The following diagram shows the entropy of the system in Reactions (1) and (3).



Copy the diagram to your notebook. Write the formulas of Reaction (1) and Reaction (3) reactants on <u>each</u> of the lines marked A and B, in the appropriate place.

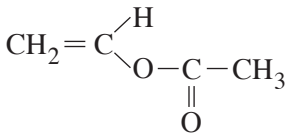
/Continued on page 6/

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

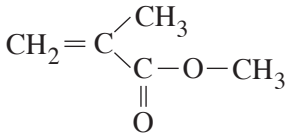
Answer one question: Question 3 or Question 4.

3. An acrylic paint contains a random copolymer and a pigment (dye).
Below are the structural formulas of three monomers:

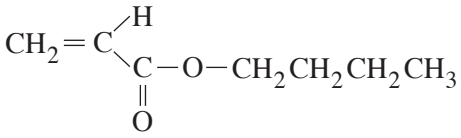
(1) Vinyl acetate



(2) Methyl methacrylate



(3) Butyl acrylate



Copolymer A or Copolymer B can be used to make acrylic paint.

א. i Write out a representative section of a random copolymer A that is obtained from monomer (1) and monomer (2).

ii Write out a representative section of a random copolymer B that is obtained from monomer (1) and monomer (3).

iii For each of the copolymers A and B, determine whether it is obtained using addition or condensation.

/Continued on page 7/

ב. Acrylic paint mixed with water — a relatively volatile solvent — as the diluent, is used to paint walls. The water evaporates off the wall and the acrylic paint remains. Some acrylic paints that have been diluted with water have a small amount of glycerol added to them.

Below are the formulas for these two diluents [מדללים]:

water, $H_2O_{(\ell)}$,

glycerol, $CH_2OH-CHOH-CH_2OH_{(\ell)}$.

i Explain why the water molecules and glycerol molecules can bind to the copolymer molecules.

ii Glycerol is less volatile than water. Give <u>two</u> reasons for this.

ג. Acrylic paint is also used to protect iron tools from rust. Rust forms in a reaction between iron and the oxygen in the air.

Copolymer A protects iron from air penetration better than Copolymer B.

Explain this fact.

ד. Under suitable conditions, both Copolymers A and B can be fully hydrolyzed.

i Write the structural formulas of <u>all</u> the products of complete hydrolysis of Copolymer A.

ii Write the structural formulas of <u>all</u> the products of complete hydrolysis of Copolymer B.

ה. The melting point, T_m, of the main hydrolysis product of Copolymer A is higher than the T_m of Copolymer A.

Provide <u>two</u> reasons for this fact, and <u>explain</u>.

/Continued on page 8/

4. **א.** Listed below are properties, a-f, of polymers:

a amorphous structure

b high percentage of crystallinity

c long chains and no large side groups

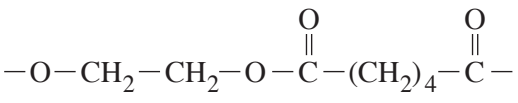
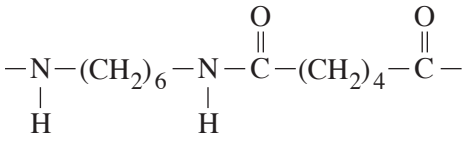
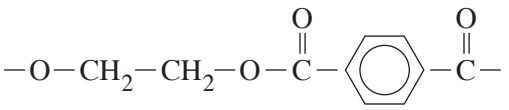
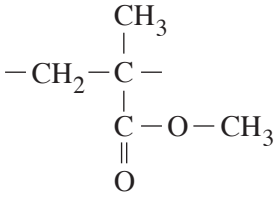
d large side groups

e rigid sections in the backbone

f covalent cross-links

List <u>three</u> of the polymer properties a-f that are compatible with polymers used to manufacture fibers.

The following table shows data for four polymers, (1)-(4), that have similar average degrees of polymerization.

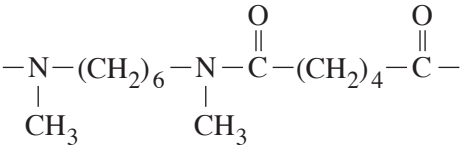
	Polymer	Structural formula of the repeating unit	T_g (°C)	T_m (°C)
(1)	Polyethylene adipate		− 45	50
(2)	Nylon 6,6		80	265
(3)	Dacron		70	265
(4)	Perspex		105	160

ב. i Explain why the T_g of polymer (3) is higher than the T_g of polymer (1).

ii Explain why the T_m of polymer (2) is equal to the T_m of polymer (3).

/Continued on page 9/

ג. When the amide hydrogen atoms on polymer (2) are replaced by methyl groups, $-CH_3$, polymer (5), which is known as nylon (N-methyl) 6,6, is obtained:

(5) 

i The T_g of polymer (5) is lower than the T_g of polymer (2). Explain why this is so.

ii Polymer (5) is not suitable for manufacturing fibers. List <u>two</u> reasons for this.

ד. The widespread use of plastic products can be harmful to the environment. One way to overcome this problem is to manufacture biodegradable [מתכלים] polymers. For example, a polymer that can be hydrolyzed into water-soluble products is a biodegradable polymer.

This is one way of reducing damage to the environment.

Polymers (1)-(4) in the table can be hydrolyzed under suitable conditions.

i Write the structural formulas for the products of complete hydrolysis of <u>each</u> of the four polymers.

ii Polymer (4) is not a biodegradable polymer, even though it can be hydrolyzed. Explain this fact.

ה. One of the hydrolysis products of polymer (2) reacted with one of the hydrolysis products of polymer (3).

Polymer (6) was obtained; its T_m is higher than the T_m of polymers (2) and (3).

Write the structural formula for the repeating unit in polymer (6).

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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. This question is about phosphorus.

א. The excited phosphorous atom, P, emits radiation. The energy of one of the photons emitted in this radiation is 5.8 eV.

i Determine whether the emitted radiation for this photon is within the range of visible light or within the ultra-violet range (UV) or within the infra-red range (IR). Show detailed calculations, and explain your answer.

ii Calculate the frequency of the emitted radiation for this photon. Show detailed calculations.

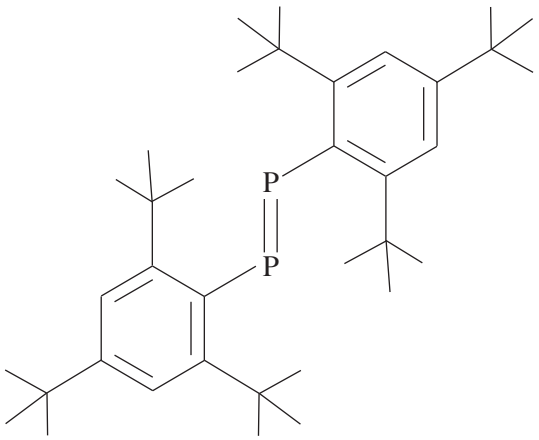
ב. The electron configuration of the phosphorus molecule, P_2, is given below.

$\sigma_{1s}^2\ \sigma_{1s}^{*2}\ \sigma_{2s}^2\ \sigma_{2s}^{*2}\ \pi_{2p}^4\ \sigma_{2p}^2\ \pi_{2p}^{*4}\ \sigma_{2p}^{*2}\ \sigma_{3s}^2\ \sigma_{3s}^{*2}\ \pi_{3p}^4\ \sigma_{3p}^2\ \pi_{3p}^*\ \sigma_{3p}^*$

i Write the LUMO level of a phosphorus molecule. Explain.

ii Which particle is more stable: the P_2 molecule or the P_2^+ ion? Explain.

ג. Below is the abbreviated structural formula for diphosphene, $C_{36}H_{58}P_2$.



Explain how the structure of the diphosphene molecule makes it a colored substance.

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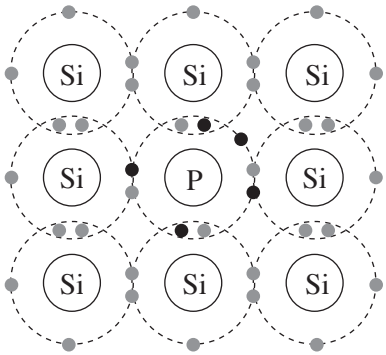
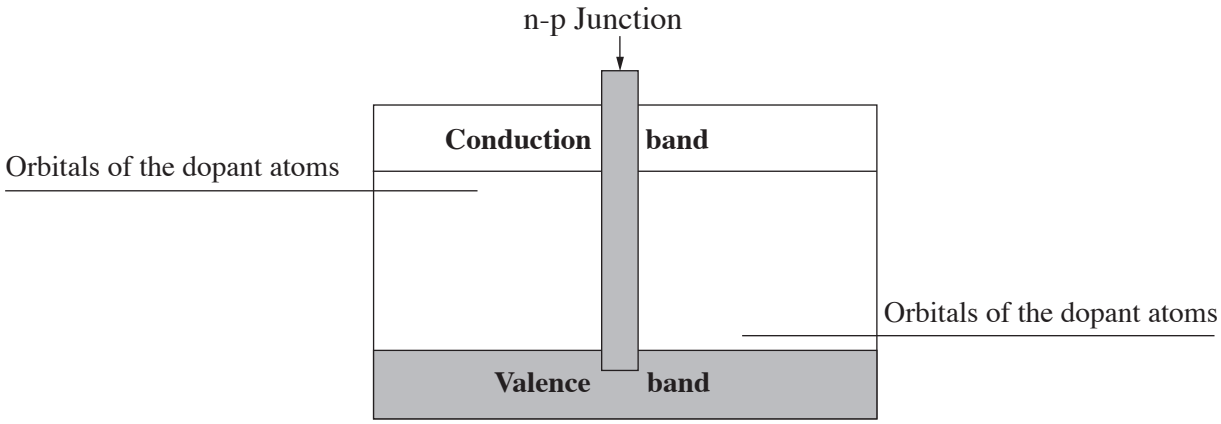
Some flashlights work with LED (light emitting diode) lamps that emit radiation at various wavelengths.

7. A LED is composed of an n-type semiconductor and a p-type semiconductor.
The figure below illustrates a section of the semiconductor structure.



i Determine whether the figure shows an n-type semiconductor or a p-type semiconductor. Explain.

ii LEDs are made of semiconductor crystals. When an electric current is passed through these crystals, they emit electromagnetic radiation in the visible light range. Below is a diagram of a LED that is obtained from connecting an n-type semiconductor to a p-type semiconductor.



Copy the diagram to your notebook.

— Mark the n-type semiconductor and the p-type semiconductor on the diagram.

— Add a battery and conducting wires to the diagram to create an electric circuit with a current.

— On the diagram, mark the charge, (+) or (-), on each of the battery terminals and mark with an arrow the direction of electron movement through the circuit.

/Continued on page 12/

ה. The lights in traffic lights are LEDs. A traffic light has a LED that emits green light and a LED that emits red light.

i Which LED has a larger energy gap, the green LED or the red LED? Explain.

ii Traffic lights also have a lamp that emits yellow light.
Calculate the energy range of yellow light photons. Show detailed calculations.

/Continued on page 13/

6. This question is about magnesium, Mg.

א. i Draw an atomic orbital (AO) diagram [דיאגרמה של אכלוס אלקטרונים] for the first three levels in the Mg atom.

Show the electrons occupying their correct orbitals.

ii Below are three electron configurations, I-III.

I. $1s^2\,2s^2\,2p_x^2\,2p_y^1\,2p_z^0\,3s^1\,3p^1$

II. $1s^2\,2s^2\,2p_x^2\,2p_y^2\,2p_z^2\,3s^0\,3p^0$

III. $1s^2\,2s^2\,2p_x^2\,2p_y^2\,2p_z^0\,3s^1\,3p^1$

Determine which configuration, I, II, or III, is the electron configuration of an excited magnesium ion, Mg^{2+}.

Explain why you rejected the two other configurations.

ב. The folowing wavelengths correspond with the magnesium atom's emission spectrum: 279 nm, 469 nm, 592 nm.

i Determine which of the given wavelengths corresponds to the lowest photon energy. Calculate this energy.

Show detailed calculations, and explain.

ii Determine which of the given wavelengths corresponds to the highest radiation frequency. Calculate this frequency.

Show detailed calculations, and explain.

iii The emission spectrum of the magnesium atom has an additional emission line at a wavelength for which the energy of the emitted photon is 3.2 eV.

Determine whether the wavelength of the additional emission line is larger than, smaller than, or equal to 469 nm. Show detailed calculations, and explain.

ג. i List one difference between a line emission spectrum and a continuous emission spectrum in the visible-light range.

ii List one difference between absorption of a photon and emission of a photon.

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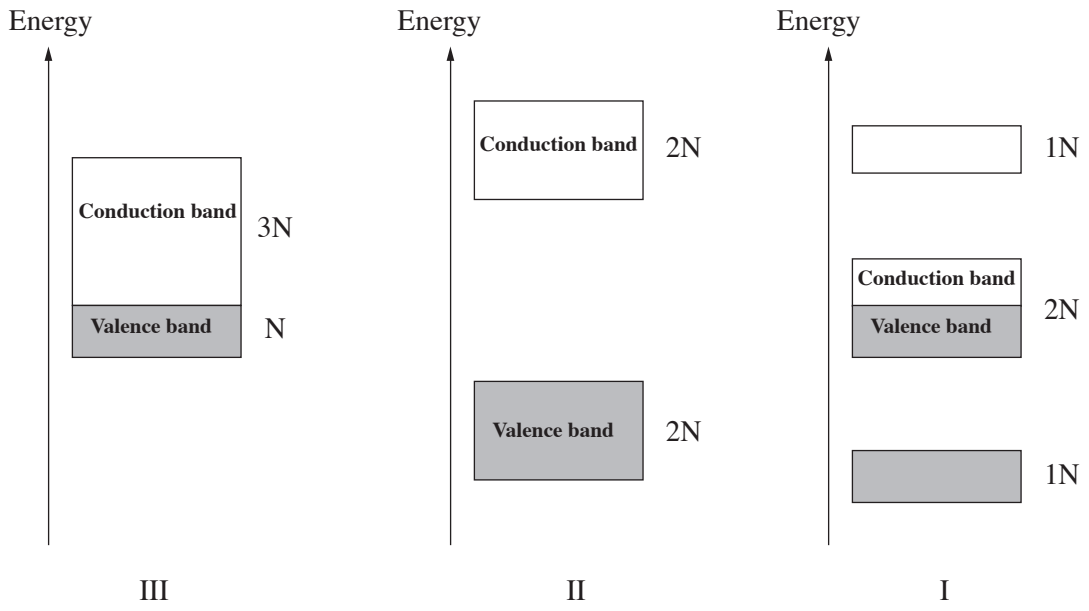
ד. The following three diagrams illustrate the valence bands and conduction bands in the final energy level of a solid.

There are 4N orbitals in each diagram.



ti Determine which of the three diagrams, I, II, or III, describes a magnesium crystal, $Mg_{(s)}$, with N atoms. Explain.

ii One of the three diagrams describes a substance that does not conduct electricity. Copy this diagram to your notebook, and mark on it the forbidden energy gap.

Good Luck!