State of Israel
Ministry of Education
Exam Type: *Bagrut*
Exam date: Summer 2018
Exam number: 37381
Attachments: (1) Periodic table
(2) Electronegativity table
(3) Formulas for calculations
(4) Functional groups
English translation (3)

Chemistry

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) 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 for Question 9.
(2) **In Part Two, there are five questions. You must answer three of them.**

Write all of your rough work (notes, calculations, etc.) on separate pages of the answer booklet only (outlines, calculations, etc.).
Write the word "טיוטה" on the top of each of these pages.
If you write any sort of work outside the answer booklet, your exam may be disqualified!

Good Luck!

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תשע"ח, 2018
מספר השאלון: 37381
נספחים: (1) הטבלה המחזורית
(2) טבלת אלקטרושליליות
(3) נוסחאות לחישובים
(4) קבוצות פונקציונליות
תרגום לאנגלית (3)

כימיה

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
סה"כ		– 100 נקודות

ג. חומר עזר מותר בשימוש:
(1) מחשבון (כולל מחשבון גרפי).
(2) 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.**

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!

בהצלחה!

Questions

Part One (40 points)

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

Before you answer, read all of the possible answers.

Four possible answers are presented for each question. Choose the most appropriate 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, mark an X with your pen 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. Given: two of the isotopes of rubidium: $^{85}_{37}Rb$ and $^{87}_{37}Rb$.

Of these two isotopes, only the isotope ^{87}Rb emits radioactive radiation.

Which statement is correct?

א. When the isotope $^{87}_{37}Rb$ emits β radiation, the isotope $^{87}_{38}Sr$ is formed.

ב. The number of neutrons in the isotope ^{87}Rb is equal to the number of neutrons in the isotope ^{85}Rb.

ג. The number of electrons in a neutral atom of ^{87}Rb is greater than the number of electrons in a neutral atom of ^{85}Rb.

ד. The compound $^{87}RbC\ell_{(s)}$ does not emit radioactive radiation.

/continued on page 3/

2. The letters X and Z are arbitrary symbols representing two elements in the third row of the periodic table.

The element X conducts electricity in solid state.

The element Z does not conduct electricity in solid state.

Which statement is correct?

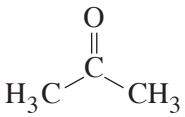
א. The ionization energy of an atom of element X is higher than the ionization energy of an atom of element Z.

ב. The radius of an atom of element X is greater than the radius of an atom of element Z.

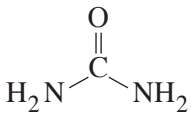
ג. The compound obtained from the elements X and Z is a gas at room temperature.

ד. The formula of the compound of element X with hydrogen, H, is XH_4 .

3. The figure below shows skeletal formulas for the molecules of two substances: acetone and urea.



Acetone



Urea

Which statement is correct?

א. The total number of electrons in a urea molecule is greater than the total number of electrons in an acetone molecule.

ב. There are hydrogen atoms, H, that are stripped of all electrons [חשופים מאלקטרונים] in the molecules of both substances.

ג. Only Van der Waals interactions are formed between molecules of urea and between molecules of acetone.

ד. Both urea and acetone molecules can form hydrogen bonds with water molecules.

4. In a laboratory, a 0.5 liter solution was prepared by dissolving 6.05 grams of iron nitrate, $Fe(NO_3)_{3(s)}$, in water. The molar mass of $Fe(NO_3)_{3(s)}$ is 242 gram/mole.

What is the molar concentration of $NO_{3(aq)}^-$ ions in this solution?

א. 0.025 M

ב. 0.05 M

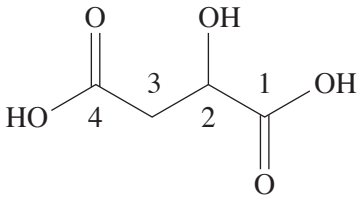
ג. 0.075 M

ד. 0.15 M

/continued on page 4/

5. Malic acid is an acid that gives fruit a tart flavor.

Below is the skeletal formula for the malic acid molecule:



The four statements א-ד, below, refer to the oxidation level of the carbon atoms in the malic acid molecule. Which is the correct statement?

א. The oxidation level of carbon atom 1 is different from the oxidation level of carbon atom 4.

ב. The oxidation level of carbon atom 2 is the same as the oxidation level of carbon atom 3.

ג. The oxidation level of carbon atom 3 is (-2).

ד. The oxidation level of carbon atom 4 is (-2).

6. The table below shows data for four aqueous solutions, I-IV:

	Solution	**Solution volume** (ml)	**Solution concentration** (M)
I	$HNO_{3(aq)}$	200	0.3
II	$NaOH_{(aq)}$	300	0.2
III	$CH_3OH_{(aq)}$	200	0.3
IV	$Ba(OH)_{2(aq)}$	150	0.2

Read the following statements א-ד. Which is the correct statement?

א. The pH of Solution II is equal to the pH of Solution IV.

ב. The pH of Solution II is higher than the pH of Solution III.

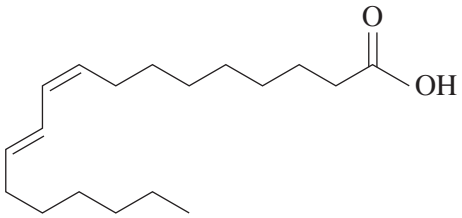
ג. When water is added to Solution I, the pH of the solution decreases.

ד. When water is added to Solution IV, the pH of the solution increases.

/continued on page 5/

7. Rumenic acid is a fatty acid found in cow milk and in cow-milk products.

Below is the skeletal formula for rumenic acid:



Read the four statements א-ד, below. Which is the correct statement?

א. The molecular formula of rumenic acid is: $C_{17}H_{32}O_2$.

ב. The abbreviated notation of rumenic acid is: C18:2ω7cis,cis.

ג. One of the double bonds in the rumenic acid molecule is in the trans configuration.

ד. Rumenic acid is an omega-6 fatty acid.

8. Given: two reactions (1) and (2):

(1) $H_{2(g)} + I_{2(g)} \longrightarrow 2HI_{(g)}$ $\qquad \Delta H_1^0 = -11kJ$

(2) $H_{2(g)} + C\ell_{2(g)} \longrightarrow 2HC\ell_{(g)}$ $\qquad \Delta H_2^0 = ?$

The table below shows bond enthalpy values.

Bond	I – I	H – I	Cℓ – Cℓ	H – Cℓ
Bond enthalpy $\left(\frac{kJ}{mol}\right)$	151	299	242	431

What is the value of ΔH_2^0?

א. $-184kJ$

ב. $+184kJ$

ג. $-52kJ$

ד. $+52kJ$

/continued on page 6/

Analysis of a Passage from a Scientific Article - Required

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

Lithium: The Key to Innovative Ammonia Synthesis

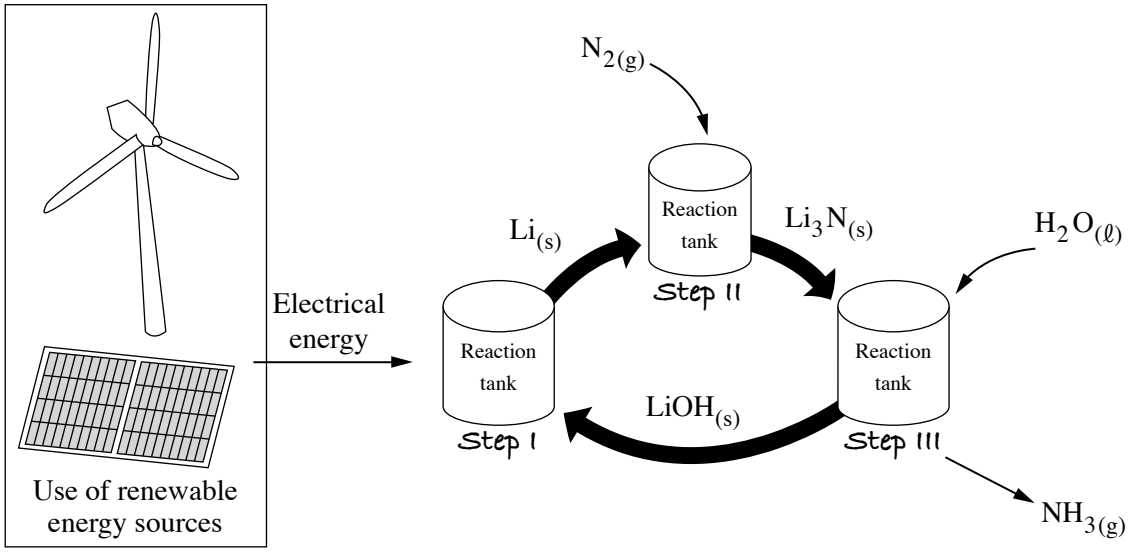
Ammonia, $NH_{3(g)}$, is an essential component in the manufacture of fertilizer for modern agriculture. Ammonia is currently synthesized industrially in a reaction between nitrogen gas, $N_{2(g)}$, present in the air and hydrogen gas, $H_{2(g)}$, under conditions of high pressure and temperature.

Producing hydrogen gas requires a lot of energy. This energy is usually obtained by burning hydrocarbon fuels, which are non-renewable energy sources. These combustion processes have a negative effect on the environment, because they emit carbon dioxide, $CO_{2(g)}$, into the atmosphere.

Scientists are therefore trying to develop alternative processes for synthesizing ammonia that would utilize renewable energy sources (such as solar energy) and would not harm the environment. In other words, they are seeking sustainable processes.

Stanford University scientists have developed a cycling process to make ammonia under atmospheric pressure in the lab. This process uses the metal lithium, $Li_{(s)}$.

The stages of this process are shown in the illustration below:



The processes that take place in each of these steps are described on the following page.

/continued on page 7/

In Step I, electrical energy from renewable sources is used to produce the metal $Li_{(s)}$: Lithium hydroxide, $LiOH_{(s)}$, is melted and an electric current is passed through it. This process produces 1 mole of lithium metal, $Li_{(s)}$, for every 1 mole of $LiOH_{(s)}$.
In Step II, $Li_{(s)}$ reacts with nitrogen gas, $N_{2(g)}$. Lithium nitride, $Li_3N_{(s)}$, is produced by the following reaction:

$$3Li_{(s)} + \frac{1}{2}N_{2(g)} \longrightarrow Li_3N_{(s)}$$

In Step III, $Li_3N_{(s)}$ reacts with water, $H_2O_{(\ell)}$. Ammonia gas, $NH_{3(g)}$, and $LiOH_{(s)}$ are produced by the following reaction:

$$Li_3N_{(s)} + 3H_2O_{(\ell)} \longrightarrow 3LiOH_{(s)} + NH_{3(g)}$$

Lithium hydroxide, formed in Step III, is returned to the beginning of the process (to Step I) to repeat the process, and so on.
The scientists emphasize that lithium is crucial to this process, because only lithium will react with $N_{2(g)}$ at room temperature.
This process, developed in the lab, is still not implemented industrially. However, the prospect of using renewable energy sources to power ammonia production is very exciting and can be expected to drive industrial innovation forward.

Source: Jeskins A. (2017),"Lithium could hold key to sustainable ammonia synthesis", Chemistry World

א. Industrial manufacture of ammonia is responsible for close to 3% of global $CO_{2(g)}$ gas emissions.
Based on the passage, explain why $CO_{2(g)}$ is emitted during the manufacture of ammonia.

ב. Describe two microscopic-level differences between $Li_{(s)}$, and $Li_3N_{(s)}$.

ג. i In Step I of the process described in the passage, $LiOH_{(s)}$ is melted. Formulate the process of melting $LiOH_{(s)}$.
ii Determine what type of reaction takes place in Step II — acid-base, oxidation-reduction, or precipitation. Explain your answer.
iii Determine whether the water in Step III is a solvent, reducer, acid, or base. Explain your answer.

ד. According to the reactions in the three stages of the process described in the passage, 3 moles of $LiOH_{(s)}$ produce 1 mole of $NH_{3(g)}$. However, this method can, in fact, produce more than 1 mole of $NH_{3(g)}$ from 3 moles of $LiOH_{(s)}$. Explain why.

ה. Scaling up the process that was developed in the lab to industrial levels will be expensive.
Write one argument in favor of the cost-effectiveness of synthesizing ammonia using the innovative method described in the passage. Explain.

/continued on page 8/

Part Two (60 points)

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

Atomic Structure, Bonds, and the Chemistry of Food

10. Coconut oil is a vegetable oil that is produced from the fruit of the coconut tree.

א. Most vegetable oils (like olive oil and corn oil) are liquid at room temperature, but coconut oil is solid at room temperature.

Statements a and b, below, discuss factors that can affect the state of matter of coconut oil at room temperature.

Determine which statement, a or b, is correct. Explain why you rejected the other statement.

a. The triglycerides in coconut oil have a high percentage of saturated fatty acids.

b. The triglycerides in coconut oil have a high percentage of unsaturated trans fatty acids.

ב. Hydrogenated coconut oil is used as a fat substitute in the food industry.

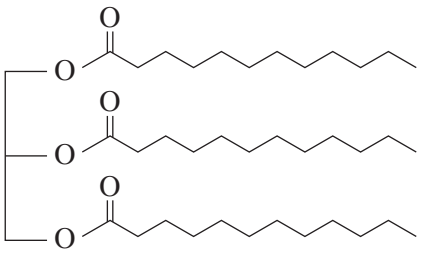
i. What is hydrogenation?

ii Determine whether the melting point of hydrogenated coconut oil is higher or lower than the melting point of natural (unhydrogenated) coconut oil.

Explain your answer.

ג. Trilaurin is a triglyceride found in coconut oil.

Below is the skeletal formula of trilaurin:



When trilaurin is hydrolyzed, lauric acid and another product are obtained.

i Write the abbreviated notation for lauric acid.

ii Write out the full structural formula of the other product that is obtained from the hydrolysis of trilaurin.

/continued on page 9/

ד. The solubility of lauric acid in water is low. Explain why.

ה. Lauric acid is also used to manufacture the soap sodium laurate, $CH_3(CH_2)_{10}COONa_{(s)}$.

i Sodium laurate is produced in a reaction between lauric acid and another substance. Determine which substance, $NaOH_{(aq)}$ or $NaC\ell_{(aq)}$, is the right substance for a reaction with lauric acid to produce this soap.
Explain your answer.

ii Sodium laurate particles form both ionic bonds and van der Waals interactions amongst themselves. Explain this statement.

/continued on page 10/

Stoichiometry and Gaseous State

11. This question relates to the gas nitrous oxide, $N_2O_{(g)}$, commonly known as laughing gas.

א. A closed container, A, with a volume of 1 liter contains 4.4 grams of $N_2O_{(g)}$.
A closed container, B, with a volume of 2 liters contains 6.4 grams of oxygen, $O_{2(g)}$.
Both containers are kept at the same temperature.
Read the following two statements, I and II.
Determine which statement, I or II, is correct. Explain your answer.

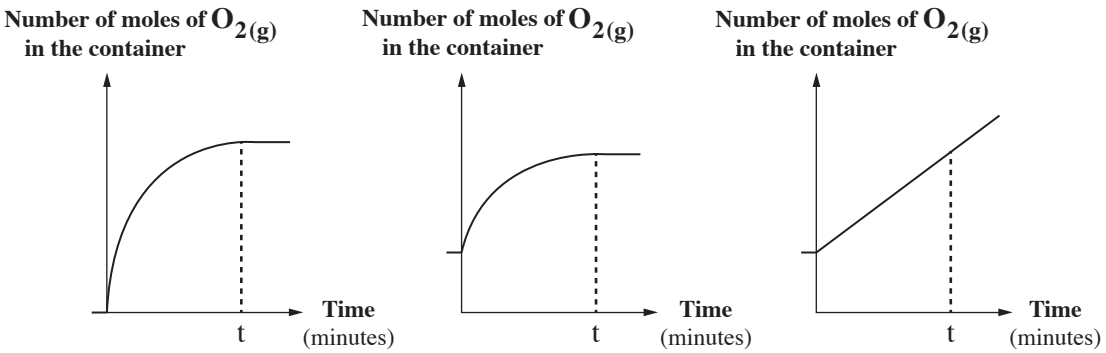
I. The gas pressure in Container A is double the gas pressure in Container B.

II. The gas pressure in Container A is the same as the gas pressure in Container B.

ב. $N_2O_{(g)}$ breaks down into its component elements, nitrogen and oxygen, at temperatures higher than 577^oC.

i Formulate and balance the decomposition reaction of $N_2O_{(g)}$ into its component elements.

ii An experiment was conducted: $N_2O_{(g)}$ was added to a closed container that contained air. The container was heated to a temperature of 600^oC for t minutes, until the gas pressure in the container stopped changing.
Which of the graphs I-III, below, correctly describes the number of moles of $O_{2(g)}$ in the container? Explain.



/continued on page 11/

ג. $N_2O_{(g)}$ is used together with $O_{2(g)}$ in dental treatment (especially with children) to reduce pain and anxiety.

Patients inhale a mixture of both gases through a mask placed over their face.

In ambient conditions, there are 30 ml of $N_2O_{(g)}$ and 70 ml of $O_{2(g)}$ in 100 ml of the gas mixture.

With each breath, the patient inhales 500 ml of the gas mixture.

Calculate the number of molecules of $N_2O_{(g)}$ that the patient inhales with each breath.

Write out your calculations.

Given:

— The volume of 1 mole of gas in ambient conditions is 25 liters.

— There are $6.02 \cdot 10^{23}$ particles in 1 mole of particles.

ד. i Nitrous oxide is stored in liquid state, at high pressure, in special tanks.

A tank used in dental clinics contains 2.92 kg of $N_2O_{(\ell)}$.

What would be the volume of this mass of $N_2O_{(\ell)}$ if stored in ambient conditions?

Write out your calculations.

Given: The volume of 1 mole of gas in ambient conditions is 25 liters.

ii $N_2O_{(g)}$ is industrially produced by heating ammonium nitrate, $NH_4NO_{3(s)}$, according to the reaction:

$$NH_4NO_{3(s)} \longrightarrow N_2O_{(g)} + 2H_2O_{(g)}$$

Calculate the mass of $NH_4NO_{3(s)}$ that is required to produce 2.92 kg of nitrous oxide.

Write out your calculations.

/continued on page 12/

Oxidation-Reduction and Stoichiometry

12. This question relates to the element chlorine, $C\ell_{2(g)}$, and some of its compounds.

א. Chlorine is one of the reactants in each of the reactions (1)-(3), below:

(1) $C\ell_{2(g)} + 2Na_{(s)} \longrightarrow 2NaC\ell_{(s)}$

(2) $C\ell_{2(g)} + F_{2(g)} \longrightarrow 2C\ell F_{(g)}$

(3) $C\ell_{2(g)} + 2H_2O_{(\ell)} \longrightarrow HC\ell O_{(aq)} + H_3O^+_{(aq)} + C\ell^-_{(aq)}$

i For each of the reactions (1) and (2), determine whether $C\ell_{2(g)}$ is the oxidizer or the reducer. Explain.

ii In reaction (3) there are chlorine atoms in three types of particles.
Determine the oxidation level of the chlorine atoms in each of the particles.

iii For reaction (3), determine whether $C\ell_{2(g)}$ reacts only as oxidizer, only as reducer, or as both oxidizer and reducer.

ב. i When chlorine gas, $C\ell_{2(g)}$, is streamed into a container that contains aluminum foil, $A\ell_{(s)}$, a reaction occurs.
Formulate and balance the reaction between $C\ell_{2(g)}$ and $A\ell_{(s)}$.

ii How many moles of electrons were transferred in a reaction in which 4.05 grams of $A\ell_{(s)}$ reacted with a suitable amount of $C\ell_{2(g)}$?
Write out your calculations.

Some compounds contain polyatomic ions of chlorine [יונים רב־אטומיים], for example: perchlorate ions, $C\ell O_4^-$, chlorate ions, $C\ell O_3^-$, and hypochlorite ions, $C\ell O^-$.
Items ג, ד, and ה relate to the uses of several of these compounds.

ג. A mixture of ammonium perchlorate, $NH_4C\ell O_{4(s)}$, and $A\ell_{(s)}$ is used as solid fuel to power space-shuttle launch rockets.
These substances can react according to reaction (4), below.

(4) $3NH_4C\ell O_{4(s)} + 3A\ell_{(s)} \longrightarrow A\ell_2O_{3(s)} + A\ell C\ell_{3(s)} + 6H_2O_{(g)} + 3NO_{(g)}$

In an experimental facility, a sample of 0.6 moles of $NH_4C\ell O_{4(s)}$ reacted with a suitable amount $A\ell_{(s)}$, according to reaction (4).
Calculate the total volume of gases obtained in this reaction. Write out your calculations.
Given: Under the conditions of this experiment the volume of 1 mole of gas is 35 liters.

/continued on page 13/

ד. Potassium chlorate, $KC\ell O_{3(s)}$, is used as a source of $O_{2(g)}$ in labs.
Under suitable conditions, $KC\ell O_{3(s)}$ breaks down into $O_{2(g)}$ and another product.
Determine what the formula of the other product is, $KC\ell$ or $KC\ell O_4$.
Explain your answer.

ה. The solution sodium hypochlorite, $NaC\ell O_{(aq)}$, commonly known as bleach, is used for disinfection and cleaning.
There are 3 grams of $NaC\ell O_{(s)}$ dissolved in 100 ml of bleach solution.
Calculate the molar concentration of $C\ell O^-_{(aq)}$ ions in this solution.
Write out your calculations.

/continued on page 14/

Acids and Bases, and Stoichiometry

13. Sulfuric acid, $H_2SO_{4(\ell)}$, is an important raw material in the chemical industry.

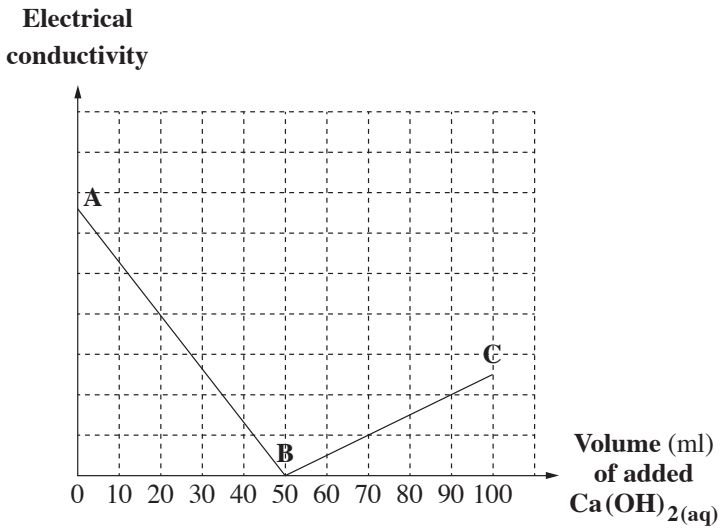
When a solution of $H_2SO_{4(aq)}$ is mixed with a solution of calcium hydroxide, $Ca(OH)_{2(aq)}$, a white solid is precipitated. This solid is calcium sulfate, $CaSO_{4(s)}$ (gypsum).

The reaction equation is shown below:

$$Ca^{2+}_{(aq)} + 2OH^{-}_{(aq)} + 2H_3O^{+}_{(aq)} + SO^{2-}_{4(aq)} \longrightarrow CaSO_{4(s)} + 4H_2O_{(\ell)}$$

Students conducted an experiment. They took a container holding 20 ml of a 0.25M $H_2SO_{4(aq)}$ solution, gradually added 100 ml of $Ca(OH)_{2(aq)}$ solution, and measured the electrical conductivity of the solution.

The graph below illustrates the change in the electrical conductivity of the solution as the experiment progressed.



א. i Explain why solution conductivity at Point B is negligible.

ii Calculate the molar concentration of the $Ca(OH)_{2(aq)}$ solution that was used in this experiment. Write out your calculations.

ב. During this experiment the students also measured the solution's pH.

i They found that the pH of the solution at Point A on the given graph was lower than the pH of the solution at Point B. Explain this finding.

ii They found that the pH of the solution at Point C on the given graph was higher than the pH of the solution at Point B. Explain this finding.

/continued on page 15/

ג. In another experiment, 200 ml of a $H_2SO_{4(aq)}$ solution with a concentration of 0.25M was mixed with 300 ml of potassium hydroxide, $KOH_{(aq)}$, with a concentration of 0.3M. The resulting reaction produced a clear liquid (no sediment was formed).

i Write out the net equation for the reaction that took place.

ii Determine whether the pH of the solution was acidic, basic, or neutral when the reaction ended.
Write out your calculations.

iii Calculate the molar concentration of the $K^+_{(aq)}$ ions in the clear solution that was obtained.
Write out your calculations.

/continued on page 16/

Energy and Reaction Rate

14. For many years, scientists and chemistry students studied how a candle burns.

The main compound in candle wax is a hydrocarbon with the molecular formula: $C_{25}H_{52}$.

They found that when a candle wick burns several processes take place: The wax melts, is absorbed into the wick, turns into gas, and reacts in a combustion reaction with the oxygen, $O_{2(g)}$, in the air.

א. Formulate and balance the complete combustion reaction of $C_{25}H_{52(g)}$.

Items ב and ג relate to an experiment that students carried out in the lab.

The students weighed a wax candle, stuck it to a dish, lit the wick with a lighted match until they had a steady flame at the tip of the candle, and then recorded their observations.

ב. i What is the system described in this experiment?

ii Determine whether the statement below is correct or incorrect.

Explain your answer.

The burning of the candle-wick supplies only the activation energy that the combustion reaction of $C_{25}H_{52(g)}$ requires.

ג. After the candle burned for 10 minutes, the students extinguished the candle and weighed it.

They found that its mass was reduced by 1 gram.

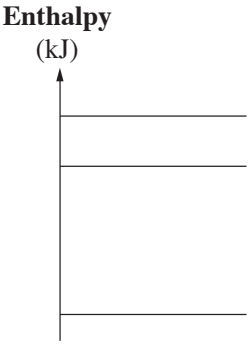
A calculation showed that the amount of energy released in the combustion reaction of 1 gram of $C_{25}H_{52(g)}$ is 34kJ.

Calculate the change in standard enthalpy, ΔH^0, in a combustion reaction of 1 mole of $C_{25}H_{52(g)}$. Write out your calculations.

/continued on page 17/

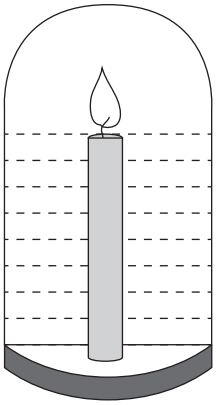
ד. i The enthalpy of evaporation of the hydrocarbon $C_{25}H_{52(\ell)}$ is $\Delta H_v^0 = 126 \frac{kJ}{mo\ell}$.
Calculate the value of ΔH^0 for the complete combustion reaction of 1 mole of $C_{25}H_{52(\ell)}$. Write out your calculations.

ii An energy diagram is shown below.



Copy the diagram to your notebook and place in the correct positions the reactants and products of both combustion reactions: the complete combustion reaction of $C_{25}H_{52(g)}$ and the complete combustion reaction of $C_{25}H_{52(\ell)}$.
Mark the appropriate ΔH^0 values on the diagram in your notebook.

ה. In the past, burning candles were also used to measure time.
To do so, candles were marked on the side with evenly spaced lines (see figure).



Read the four statements (1)-(4), below.
Specify which of the statements describe the burning of a candle being used as a device for measuring time.

(1) The candle burns at a steady rate.

(2) The change in candle mass per time unit is steady.

(3) The amount of energy released by the burning candle per time unit is steady.

(4) The temperature of the candle flame rises steadily.

Good Luck!