Country: _____ Language: _____

2009 INTERNATIONAL FIBRE YEAR

TEST 1

Murcia, March 31st, 2009

Country: _____ Language: _____

Introduction

Lady Silky was totally at home in the world of business. The money she had inherited had permitted her to found several companies, in which she held important positions, and to invest in the stock market – usually successfully. Her long standing romantic relationship with a rich American, Mr Cottonfield, did even more to cement her solvency. However, at fifty, she tried to spend as much time as possible in the house she had built in Hope, in the west of England, where she enjoyed its tranquillity, went for long morning walks in the country and lovingly tended the garden.

That particular Saturday afternoon, she had fallen asleep on the sofa, as she frequently did, after the lunch prepared by her companion. When she woke from what her Spanish friends called her "siesta", the television was showing a film, whose title immediately caught her attention: SILK.

The film combined romance with business. It described the trips made by a French businessman from France to Japan to buy silkworms to supply the factories of the town where he lived. The action was set at the time of the 1860 epidemic of pebrine disease which affected silkworm farms all over the world.

Interested in the subject which she knew little about, rather than the romantic aspects of the film, Lady Silk wanted to learn more, especially from a scientific and technical point of view, since she had recently read a newspaper article entitled ***Chinese astronauts to eat silkworms in space*** based on the declarations of the scientist Yang Yunan, one of the participants in the XXXVI International Scientific Assembly for Space Research. "*Worms, particularly silkworms, may soon become part of the diet of Chinese astronauts in space due to their high protein content, which the human organism can easily assimilate. From a practical point of view, they are easy to breed, they grow rapidly, and they do not need a lot of space*" *said Yunan. In their website, the Xinhua state agency published that Chinese experts have discovered that five or six silkworms contain the same quantity of protein as an egg, besides which the cocoons contain eight types of amino acids considered of vital importance for humans, which has led to new research being carried out.*

Lady Silky switched on her computer and entered her name in the search engine: *silky*. She then removed the final *y* and pressed ENTER. In one of the links she found the following.

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The cost of Silk

"*Silk is a natural fibre of animal origin which has long been used for making fine clothes. It has always been appreciated because of its smoothness and strength. Discovered in China (according to legend around 2500 BC), its origin was a well kept secret for two thousand years. During this period silk was only produced in China, from where it was exported to different parts of Asia, Europe and North Africa. This trade represented an enormous source of wealth for China, which explains why the production process was a closely kept secret (attempts to reveal the secret were punishable by death). Moreover, the silk trade was what can only be described as the first process of industrial globalisation: the Silk Road was a long and arduous path connecting the east with the west. It was slow as the silk was transported on beasts of burden (mules and camels), while the traders also took with them other products - not only to feed themselves but also to trade along the route and to take back to China. The result was an intercontinental highway that blossomed into variety of human achievements and settlements, leading the foundation of large cities and the cultural interchange that inevitably accompanied them.*

However, the secret could not be kept forever and in the XV century it reached Europe. Industries related with silk sprang up in southern Europe, particularly in Italy, France and Spain (especially in the regions of Valencia and Murcia), which spelled the beginning of the end for the Silk Road. It was by now widely known that silk was a fibre spun by the larvae of an insect: the silk moth. This insect, whose scientific name is Bombyx mori, is a Lepidoptera (butterfly) whose larval form is a herbivorous worm that grows until it stops eating and begins to produce, through special glands (the sericigenous glands) a viscous solution consisting of two proteins, fibroin and sericin. The first of these polymerises upon contact with air, giving rise to a continuous thread of silk (one worm can produce up to 1.6 km of thread), used to form a protective cocoon. Inside this cocoon the worm will metamorphose into its adult form which will be able to reproduce the butterfly or moth. This adult form has no digestive system because it does not need to feed. This contrasts with the silkworm, which hardly stops eating. Its diet consists of mulberry leaves, preferentially the white species, whose scientific name is Morus alba. During its lifetime before metamorphosis, the worm needs to obtain from the leaves sufficient nutrients to grow, store the proteins to be used to spin the silk thread and construct its new form during metamorphosis, form reproductive organs capable of producing a sufficient number of spermatozoids and ovules (which contain lipoproteins that are stored in the vitellus) to ensure that a new pair will exist in the following stages to reproduce. In this way, the worm acts as a factory to transform proteins of a vegetal origin into one of animal origin which will give rise both to the structures of its body and to silk."

Fascinated by what she read, she and Mr. Cottonfield decided to travel to Murcia, some close friends of theirs lived, in order to know *in situ* the present day situation of the silkworm farming and the silk industry in general. With an eye on possible business opportunities and to have suitable scientific advice, they took with them Dr. Nylonskaya, who had previously run the village pharmacy and who, since her retirement, had become a regular visitor to Lady Silky's country house. She frequently accompanied Lady Silky on her walks in the country and both shared a common scientific curiosity.

Once in Murcia, their friends Patricio and Fuensanta, who knew the purpose of Lady Silky and Mr. Cottonfield's visit, informed them that several years previously a magazine had published a report on a Murcian businessman who had noticed a great improvement after using a silkworm extract to treat a carcinoma he had had surgery for. They also said that a local newspaper had recently reported that a group of scientists from Murcia and China had begun a collaborative project to produce therapeutic proteins from silkworms and the silk from their cocoons for use in vaccinations and as antibodies, and as a support for growing human tissue-forming cells. In charge of the project were agricultural engineers from the Murcian Institute for Agricultural Research and Development (IMIDA in Spanish), and Professors form Zheijiang University.

Bearing this in mind and thinking that there might be a business opportunity in what they had learnt, on the advice of Dr. Nylonskaya, they decided to carry out some previous research to establish the viability of the idea. They therefore contacted the University of Murcia, who, in turn, thought it would be a good idea to hand the work to the participants in EUSO 2009. This would serve a base for awarding medals and diplomas, while, at the same time, the resulting reports would be available in several languages.

The participants had to carry out the following tasks.

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TASK A

Dr. Nylonskaya wanted to evaluate the biological cost of obtaining adult silkworms to produce silk.

Since *silkworms, before metamorphosis, must obtain sufficient nutrients from mulberry leaves to, among other processes, grow and store the proteins that they will use to spin the silk thread, which itself is a protein,* they realised that it would be interesting to measure the amount of protein contained in a mulberry leaf and in a silkworm's body. Knowing this amount, the total weight of the worm and the mean weight of a leaf, it should be possible to calculate the total weight of mulberry leaves necessary for a worm to feed on during its lifetime.

Among the different methods used to quantify proteins, Dr. Nylonskaya suggested using Lowry's method with some modifications.

In this method, a colour is generated in the solution containing the substance to be analysed and this colour is then measured in a spectrophotometer. The measurement is made possible because the components of the solutions absorb part of the light which is directed at them, the degree of absorption being a function of the wavelength of the light radiation and the concentration of the substance in question. There is a linear relationship between the absorbance of the sample and the concentration, within a given range. This relation is established by Lambert-Beer's law:

$$\boldsymbol{A = \varepsilon \cdot l \cdot c}$$

where $\boldsymbol{A}$ is the absorbance measured by the spectrophotometer, $\boldsymbol{\varepsilon}$ is the molar absorption coefficient of the coloured substance, $\boldsymbol{l}$ is the distance that the light beam has to cross (the absorption pathlength, which is simply the thickness or width of the cuvette), and $\boldsymbol{c}$ is the molar concentration. This means that for a given cuvette

$$\boldsymbol{A = K \cdot c}\ ,$$

where $\boldsymbol{K}$ is a constant.

A spectrophotometer is basically a device provided with a lamp that emits light at a controlled wavelength. The light crosses a given space in which a cuvette or tube is introduced. This contains the solution whose absorbance we wish to measure. Part of the light passing through the solution is absorbed, and the loss of light is detected by a sensor placed on the opposite side of the cuvette.

Lowry's method permits the soluble proteins present in a sample to be evaluated quantitatively. When a suitable reagent is added to a sample it forms a coloured complex with the proteins, the intensity of this colour being proportional to the concentration, according to Lambert-Beer's law.

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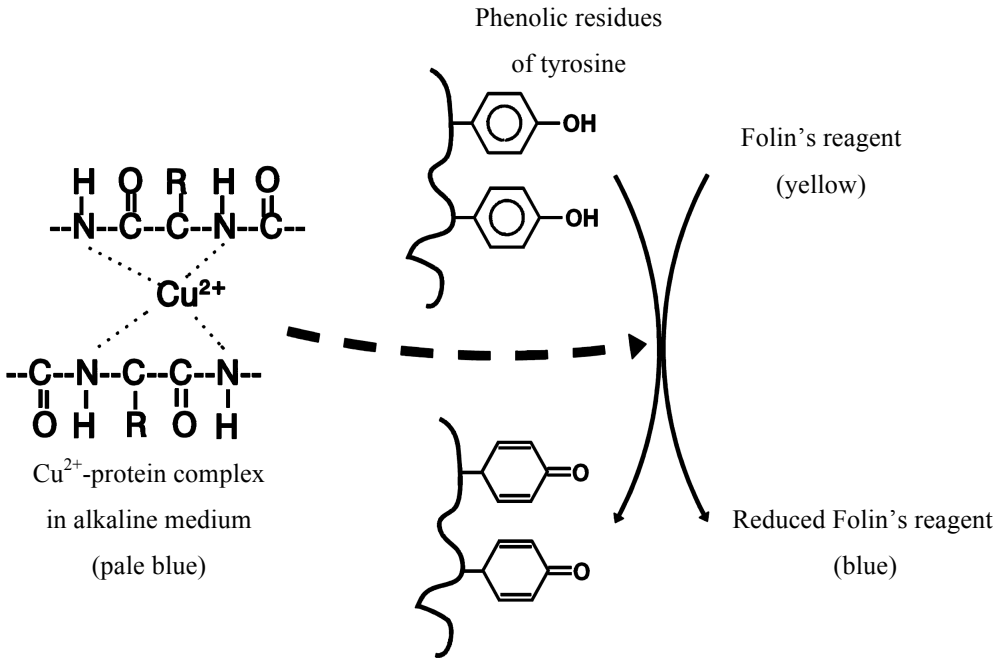
The method consists of two stages as represented in the diagram:



1. When Cu^{2+} ions are added in an alkaline medium they bind to the proteins to form complexes with the nitrogen atoms of the peptide bonds. These Cu-protein complexes are a pale blue in colour. They also cause the cleavage of the tridimensional structure of the protein, releasing the phenolic residues of the aminoacid tyrosine that take part in the second step. For the copper ions to be present in an alkaline solution it is necessary to complex them with ions 2,3-dihydroxibutanedioate (tartrate) as ligands.

2. The reduction, also in basic medium, of Folin-Ciocalteau reagent by the phenolic groups of the tyrosine residues present in most proteins with copper acting as catalyst. The main constituent of the Folin-Ciocalteau reagent is a mixture of phosphotungstic acid and phosphomolybdic acid in phenol, which is yellow, and when it is reduced by the phenolic groups it forms a bright blue complex. The final product absorbs light at 590 nm.

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To carry out these reactions, the following equipment will be necessary:

- a marker pen
- plastic flasks (25 mL)
- a container for the flasks
- variable volume micropipette marked 0.5 to 5 mL
- pipette tips
- a 50 mL burette
- volumetric flask (250 mL)
- spectrophotometer
- cuvette
- paper tissue
- beaker to deposit cuvette washings
- **[reagent *A*]**: aqueous solution of 2% sodium carbonate, $Na_2 CO_3$ and 0.1 M in sodium hydroxide, NaOH.
- **[reagent B_1]**: aqueous solution of copper(II) sulphate, $Cu SO_4 \cdot 5H_2O$, at 1%
- **[reagent B_2]**: solution of potassium and sodium tartrate at 2%
- ***reagent C***: prepared at the time the experiment begins, mixing reagents **A**, $\mathbf{B}_1$ and $\mathbf{B}_2$ in suitable proportions (volume)
- Folin-Ciocalteau reagent, labelled **[F-*C* reagent]**
- Standard solution of bovine serum albumin, labelled **[BSA]**, 0.75 g L^{-1}
- Sample of mulberry leaf extract, labelled **[M]**
- Sample of silk worm extract, labelled **[SW]**

Material and reagents should be on the bench or shelf and must be checked before starting experiment. Contact the laboratory supervisor if anything is missing.

Experimental procedure

To determine the concentration of proteins in the problem samples (mulberry leaf and silk worm extracts) it is necessary to measure first the absorbance data corresponding to known concentrations of a standard solution of BSA (0.75 g L^{-1}) and then to obtain the corresponding calibration line. The concentration of the problem samples can be determined by interpolating the absorbance values on this standard line.

First label the flasks supplied from 0 to 9. Flask 0 will only contain the adequate proportions of distilled water and the reagents, and will serve to adjust the spectrophotometer to zero absorbance. The aim is to determine the concentrations of soluble proteins in the mulberry leaf (M) and silkworm (SW) extracts.

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Follow the protocol described below:

a. Using the micropipette and suitable tips, drop into the flasks the quantities of water, standard albumin solution and leaf and silkworm extracts that are listed in Table 1.

Table I

Flask		water (mL)	BSA sol. (mL)	Problem samples (mL)
0		5.0	--	--
1		4.5	0.5	--
2		4.0	1.0	--
3		3.5	1.5	--
4		3.0	2.0	--
5		2.0	3.0	--
6	M_1	4.0	--	1.0
7	M_2	2.5	--	2.5
8	SW_1	4.0	--	1.0
9	SW_2	2.5	--	2.5

b. Prepare reagent C: Using the micropipette, drop 2.5 mL of reagent B_1 and 2.5 mL of reagent B_2 in the volumetric flask, and add reagent A to bring the total volume to 250 mL. Shake well.

c. Place the reagent C in the burette and add 10 mL of it to each flask. Mix well and leave to rest 10 minutes (approximately) in the dark (inside a drawer or cupboard).

d. After this interval of time has elapsed, add 1 mL of Folin-Ciocalteau reagent by means of micropipette to every flask and shake well. Let the flasks rest for another 30 minutes in the dark for the colour reaction to develop fully.

e. Check that a wavelength of 590 nm is indicated in the spectrophotometer.

f. Once this time has elapsed, adjust the Absorbance to 0 with the blank (flask 0). To do this, first rinse the cuvette with a little of the solution from flask 0 and poured it into the beaker. Next fill the cuvette to about ¾ of its total capacity. Dry and clean the outside of the cuvette (with tissue paper) and introduce the cuvette into its holder in such a way that you can see the transparent side, and put it into the spectrophotometer so that the light ray cross the solution. Press **0A** key and check that the apparatus screen shows -.000.

g. Record the corresponding absorbance readings for each of the other solutions (IN THESE CASES DO NOT PRESS ANY KEY).
h. Write the readings in the Answer Sheet (A.1). Calculate and note in the corresponding column the mass of protein contained in each flask.
i. Represent in the form of a graph the absorbance values of each albumine solution *vs.* the volume of protein solution used for preparing each flask and draw the line that best fits them, which should be a straight line. (A.2).
j. Calculate the slope of the line obtained (A.3).
k. Using the graph, determine the mass of protein to be found in one litre of each problem sample (A.4) (A.5).

One the experiment has finished, the liquid residues of washing the cuvette (in the beaker) and the liquid in the flasks must be poured into the waste container, labelled WASTES OF PROTEIN, placed in a corner of the lab.

Taking into account the following:

- the mulberry leaf extract sample was obtained from 3 g of dry leaves, dissolved to a final volume of 1 L;
- a fresh mulberry leaf has a water content of approximately 75%;
- the mean weight of a fresh mulberry leaf is 12 g.
- the mean weight of an adult silkworm is 9 g,
- the silk worm extract was obtained from 6 g of silkworm (water content 80%) also dissolved in a final volume of 1 L;

make the corresponding calculations in the Answer Sheet:

What is the total protein content (in mg) of a fresh mulberry leaf? (A.6).

What is the total protein content (in mg) of a silkworm of average weight? (A.7).

If we suppose that only 5% of the protein content of a mulberry leaf remains in the silkworm's body (the rest is used by the worm for vital processes during its lifetime), what mass of leaves will a silkworm eat during its lifetime? (A.8).

Knowing that a silkworm lives for about 30 days, how many leaves does a silkworm eat per day on average? (A.9)

What is the value of

$$\frac{\text{mass of protein per gram of dry silkworm}}{\text{mass of protein per gram of dry mulberry leaf}} \; ?$$

(A.10)

Each of the adhesive labels provided corresponds to a metamorphosis stage of Lepidoptera. Following the arrows, stick them in the correct order in the boxes (A.11).

(The adhesive labels are in the folder together with the graph paper.)

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TASK B

Mr. Cottonfield is not in favour of investing in the silkworm business. He thinks that silk has few outlets since cheaper, artificial, man-made fibres with similar or better qualities have long existed on the market.
He wants to convince Lady Silky that such fibres are very easy to obtain and sets out to do so. A literature search gives him the information he wants.

Synthesis of nylon 6.10

WARNING:
- Gloves and safety glasses must be worn.
- No waste products are to be poured down the sinks.
- Liquid residues should be poured into the ORGANIC WASTES container; glassware should be washed with a water-acetone mixture; mixture should afterwards be disposed of in the same containers; only then can the glassware be washed with water in the sinks.
- The solid wastes should be picked up with paper.
- The laboratory must be well ventilated.

CAUTION: Cyclohexane is a volatile and colourless liquid with a penetrating smell. Prolonged exposition to its vapours must be avoided; consequently it is mandatory that after preparing the nylon the waste be poured into the ORGANIC WASTES container placed in another corner of the lab and clearly labelled.

Polyamides are synthetic materials; they are usually used in fibre form and the most common are known as nylon.

At present nylon 6.6 and 6 represent almost all the nylon produced to obtain fibres for the textile industry, although others are also important: nylon 11, nylon 12, nylon 6.10 and nylon 6.12 among others.

As to the names used for nylon, when the name contains only one number the nylon comes from a lactam or a ω-amino acid (hydrocarbon chain with an amine group at one end and a carboxyl group at the other). If two numbers are used, separated by a point, the nylon is obtained by the reaction of a diamine with a diacid or acid dichloride or a diester, the first figure corresponding to the number of carbons of the diamine and the second to the number of carbons of the second monomer.

Nylon 6.10 can be synthesised by the reaction of a diamine (hexane-1,6-diamine or hexamethylendiamine) and an acid dichloride (decanedioyl dichloride). The overall reaction is as follows:

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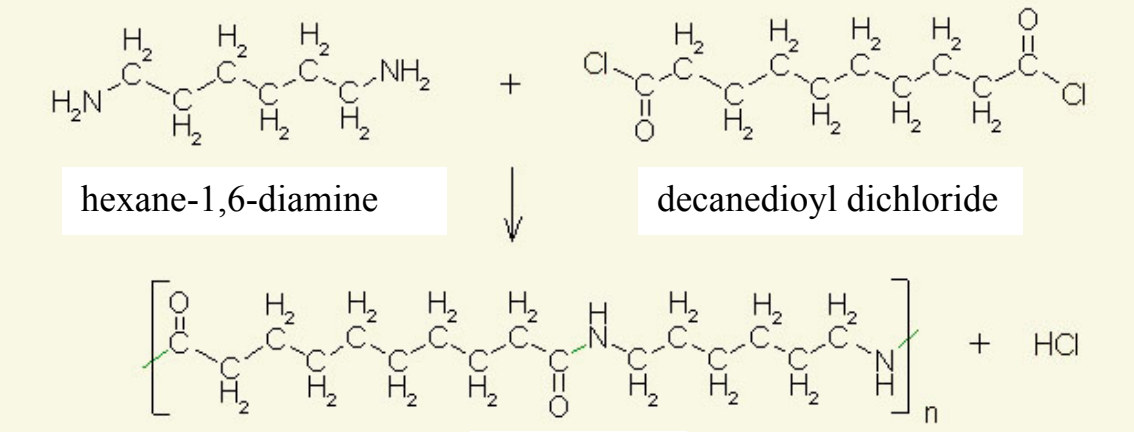

Reaction B.1

The diamine (R 21/22-34-37, S 22-26-36/37/39-45) is dissolved in water and the dichloride (R 34, S 26-36/37/39-45) in cyclohexane (R 11, S 9,16,33). As these solutions are immiscible, polymerisation only occurs in the liquid-liquid interface (contact area).

To carry out the task, you will need:

- two 50 mL glass beakers
- two 100 mL glass beakers
- a glass rod
- piece of wire with one end bent into a hook
- one 25 mL glass measuring cylinder
- one 25 mL plastic measuring cylinder
- micropipette (0.5-5 mL) (used in task A)
- a balance
- hexane-1,6-diamine solution in water, labelled **[HMDA]**
- decanedioyl dichloride in cyclohexane solution **[SDC]**. (SEE WARNING)
- methylene blue, **[Met. Blue]**
- sodium hydroxide solution, 0.1 M in NaOH , **[NaOH 0.1 M]**
- 0.05 M hydrochloric acid solution, **[HCl 0.05 M]**
- flask containing aqueous solution of acetone, **[Water-Acetone]**
- pH-meter with electrode
- burette and holder
- magnetic stirrer with 3 stirring bars

All the above items should be on the bench or shelf. Please contact the laboratory supervisor if anything is missing.

Having obtained all the information necessary and with all the above equipment at his disposal, Mr. Cottonfield realises that the concentration of the HMDA is not written on the flask, presumably because the label had fallen off. However, this was

easy to determine. To do this he would have to titrate a given volume of HMDA (which is a basic solution) with an acid solution. Using the pH-meter (already calibrated), it is possible to measure the pH values of the solution when different volumes of acid solution are being added. This will give the curve representing the pH *vs*. the volume of acid added allowing the concentration of HMDA solution to be obtained.

Using the micropipette, drop 5 mL of the HMDA solution into one of the 100 mL beakers. Using the plastic measuring cylinder, add approximately 25 mL of distilled water. Place the beaker, with a stirring bar inside, over the magnetic stirrer.

Introduce the electrode (after removing the protection) into the liquid almost to the bottom and close to the side; using the clip fix the electrode in position. **WARNING: the stirring bars must not hit the electrode when moving.** Switch on the stirrer at moderate stirring speed and place the burette tip over the glass beaker.

Prepare a table in the Answer Sheet and write the pH values corresponding to each addition of acid solution. Note that when the end point is close, the volumes added should be smaller.

The titration will be finished when the pH-meter indicates acidic values. Repeat the titration with other 5 mL sample of basic solution (HMDA). Plot the data of each titration on different graph sheets and draw the appropriate curve. The end point corresponds to the inflection point on the graph (B.1).

In the corresponding box of the Answer Sheet, calculate the concentrations of the HMDA solution obtained in each one of the titrations and note the mean value (B.2).

Now you are ready to synthesise nylon 6.10, which, following the suggestions of Dr. Nylonskaya, you should do in duplicate, varying the conditions slightly.

Pour into a 50 mL glass beaker, 5 mL of HMDA solution and 5 mL of water. Add two drops of methylene blue. Using the glass cylinder measure 20 mL of organic solution of decanedioyl dichloride (REMEMBER THE SAFETY WARNINGS) and pour it slowly and carefully into the flask, with the help of the glass rod letting the liquid dribble down the sides of the glass. DO NOT SHAKE THE LIQUIDS.

A white film (nylon) will form at the interface of the two liquids. Catch the polymer with the wire (hook) and pull it up through the organic solution. Roll the fibre extracted around the glass rod and turn so that the thread wraps itself round the rod. It is important to turn the rod at constant speed so that the thread thickness is almost constant. If the thread breaks, hook the polymer again and wrap it round the rod. Continue this operation until it is too difficult to hook the nylon or until the basic solution is used up.

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When you have finished take out the nylon ball from the rod, pushing it with your fingers (DON'T FORGET TO WEAR GLOVES) in the flask with the acetone solution, stirring it with the rod to wash it.

Repeat the process using now 5 mL of the amine solution and 5 mL of sodium hydroxide solution (instead of water) before adding the methylene blue. After adding the organic solution (with the same care) proceed as before to obtain the new nylon ball. Place the ball of nylon in acetone solution and stir with the rod for a short time.

Now answer the following questions in the Answer Sheet.

How much nylon have you obtained now? More, less or the same? (B.3).

Why? (B.4).

a) The sodium hydroxide acts as catalyst.
b) The interface is bigger.
c) The sodium hydroxide reacts with the hydrochloric acid formed, fulfilling the Chatelier's Principle
d) The sodium hydroxide neutralised all the hydrochloric acid formed.
e) The sodium hydroxide does no affect the reaction since the same quantity of nylon is obtained.

(B.5) Balance the chemical equation (reaction B.1)

(B.6) Knowing the amount of HMDA reacted and the fact that it is the limiting reagent, what is the theoretical maximum amount of nylon that can be obtained? (H=1, C=12, N=14, O=16, Cl=35.5)

(B.7) Assuming that the average molecular mass of nylon 6.10 is 150000 g mol^{-1}, calculate the average polymerization degree of this polymer (*n* in the formula).

Answer questions B.8 and B.9 in the Answer Sheet.

R-Phrases – Hints to special risks

The separation of two R-Phrases by a hyphen (- , e.g., R12-20) means that the R-Phrases R12 **and** R20 have to be considered (and not R12 to R20). If R-Phrases are separated by a slash (/, e.g., R26/27/28) then all three R-Phrases are indicated: R26 **and** R27 **and** R28 (combination of R-Phrases).

R11: Highly flammable
R21/22: Harmful in contact with the skin and if swallowed
R34: Causes burns
R37: Irritating to respiratory system

S-Phrases – Safety Recommendations

The separation of two S-Phrases by a hyphen (- , e.g., S10-23) means that the S-Phrases S10 **and** S23 have to be considered (and not S10 to S23). If S-Phrases are separated by a slash (/ , e.g., S36/37/38) then all three S-Phrases are indicated: S36 **and** S37 **and** 38 (combination of S-Phrases).

S9: Keep container in a well ventilated place
S16: Keep away from sources of ignition - No Smoking!
S22: Do not breathe dust
S33: Take precautionary measures against static discharges

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S36/37/39: Wear suitable protective clothing, gloves and eye/face protection
S45: In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible)

TASK C

Lady Silky wants to know something about the mechanical properties of silk and nylon, since she thinks the natural fibre must be stronger, at least that is the impression she has concerning spider thread after reading several articles in specialised journals. As far as she remembers, one of the articles said: *A spider's thread may be five times more resistant than a filament of steel of equal thickness. It has even been said that a spider thread as thick as a pencil would be able to stop a Boeing 747 in full flight! A spider thread can be stretched to more than 30 times its original length without breaking. Indeed we are talking about one of the strongest materials known*. Why don't we try to check this with the silk and nylon.

Young's modulus of silk and nylon

If a traction force, F, is applied to a wire or thread of an initial length L_0, the wire will be stretched by ΔL. This stretching is directly proportional to the length of the wire, and to the traction force and inversely proportional to the cross-section of the wire, S. Then we can write:

$$\Delta L \propto L_o \frac{F}{S} \rightarrow \frac{F}{S} = E \frac{\Delta L}{L_o}$$

This equation is known as Hooke's law. The proportionality constant, E, that appears in the equation is called the Young's modulus and is related to the elasticity of the material.

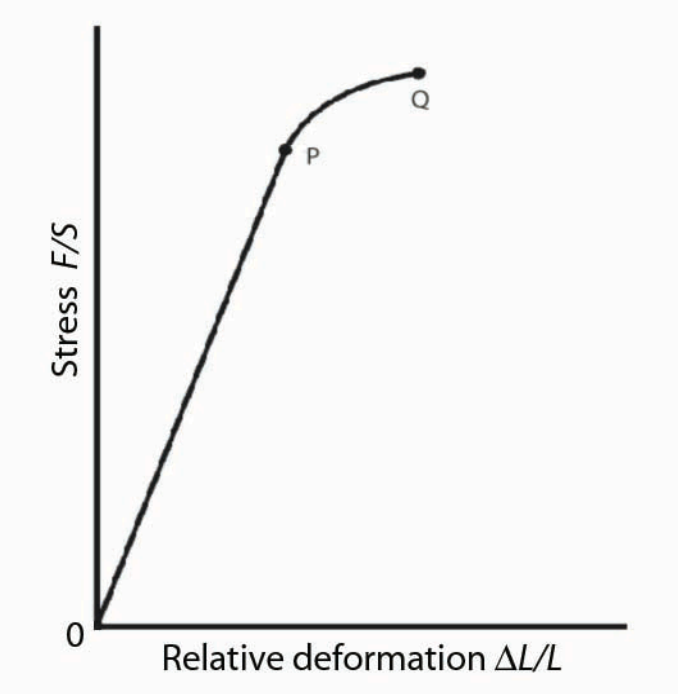
For elastic materials, if the normal stress (F/S) is plotted vs. the relative deformation ($\Delta L/L_0$), a graph such as that showed in the figure is obtained.

In the experimental conditions in which Hooke's law (0-P line in the graph) is obeyed, the material recovers its length when the force applied ceases. We will work always in this range.

To given an answer to Lady Silky, we shall measure the Young's modulus of a silk thread and a nylon thread. Dr. Nylonskaya indicates that the radius of both threads can be obtained determining previously the volume of a piece of each, assuming them regularly cylindrical,

$$V = S \cdot L = \pi \cdot r^2 \cdot L$$

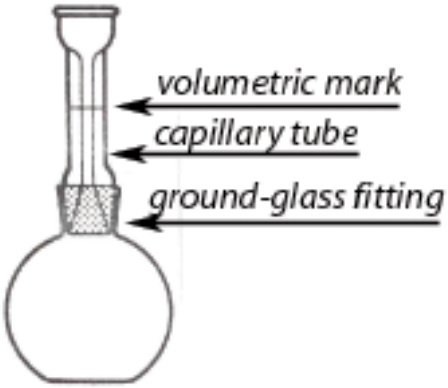
where S is the cross section and L the length of the thread. In this way, the radius r can be calculated.



To determine the volume of a piece of thread and the density of the material at the same time, we shall use a pycnometer.

For this, we shall use:
- a pycnometer
- an analytical balance (± 0.001 g)
- a glass Pasteur pipette
- a chopstick
- a nylon thread (1.5 m long)
- a silk thread (1.5 m long)

The **pycnometer** (from Greek *pyknós*, meaning "density"), is a glass flask, with a close-fitting ground glass stopper and a capillary at the end, so that a given volume can be accurately measured. This enables the density of a fluid to be measured accurately, by reference to an appropriate working fluid such as water. The density of a solid can also be determined as long as it is insoluble in water and denser.



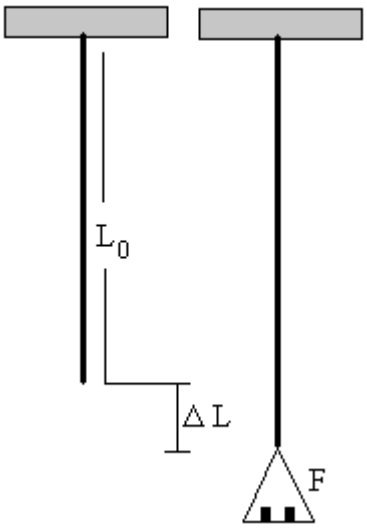
To obtain the density of silk or nylon, along with the corresponding volumes of the lengths of thread, proceed as follows:

- Make a ball with the nylon thread with the help of the chopstick, make sure that the ball is as compact as possible and small enough to pass through the opening of the pycnometer.
- Determine the mass of the ball: M_{NYLON}.
- Check that the pycnometer is clean. Fill it completely with distilled water. Put the ground glass stopper in its place, then the level of water will be above the mark of the capillary. Be sure that no air bubbles are trapped (a few gentle taps on the sides will help). By using the Pasteur pipette (or a small piece of rolled filter paper) remove the excess of water above the mark.
- Place both, the pycnometer (full of water as described) and the nylon in the balance. Determine the mass of both items together: $M_{p+w} + M_{NYLON}$

- Remove both (pycnometer and ball) from the balance. Open the pycnometer and introduce the nylon ball inside (if necessary use the Pasteur pipette in order to sink the nylon ball and release air bubbles, be sure none are trapped), fill with some more water. Put the ground glass stopper in its position and remove water till the mark level. Dry carefully the outside of the pycnometer with tissue paper.
- Finally, place the pycnometer containing the nylon ball in the balance and obtain a new mass: $M_{p+w+NYLON}$.
- Write all these measurements in the Answer Sheet (C.1)
- Calculate the mass of water that has been displaced by the nylon thread, M_{wd}.
- Assuming that the density of water (ρ_w) at the lab temperature is 1,00 g cm^{-3}, calculate the density (ρ_{NYLON}), the volume (V_{NYLON}), the cross section (S_{NYLON}), and the radius (r_{NYLON}) of the nylon thread.
- Assume that the cross section remains constant during the experiment.

Do not forget to write all these results in the Answer Sheet (C.1).

Repeat all the above procedure with the silk thread and write all measurements and calculations in the Answer Sheet (C.1).



Let us turn back to the modulus of elasticity. In the mean time Mr. Cottonfield has hung two threads (one of silk and the other of nylon) near the window (see figure). DO NOT TOUCH THE THREADS NOR UNRAVEL THE WEIGTH HANGED. The weights hanging from them will permit them to react almost linearly to the forces to which they are going to be submitted.

On the table near to where the threads are hanging, you should find:

6 masses of 20 g
6 masses of 50 g
1 magnifying glass
1 measuring band.

The first thing we need to know is the length of the thread in this position. To this end, use the measuring band (remember that the threads has to remain hanged in its position). Write the lengths in the Answer Sheet (C.2).

Starting with the nylon thread and using the magnifying glass, write the position of the cardboard pointers with respect to the ruler on the aluminium profile. Write this in the Answer Sheet (C.3) as "initial position". DO NOT MOVE THIS REFERENCE

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SYSTEM. Place a 20 g mass on the pan, wait three minutes and observe the new position of the pointer. Continue adding 20 g masses (at least four more times) writing the new position each time (waiting three minutes and writing the new position of the pointer each time!). Draw up a table in C.3 including the following data:

- mass used in each measurement,
- position of the pointer,
- deformation (increase in length) corresponding to the total mass hanged in each measurement,
- the ratios between the force applied (due to the mass hanged) and the cross section of the thread, $g = 9.8$ m s^{-2}
- the ratio between the deformation in each case and the initial length of the thread.

In an XY graph, plot the F/S values vs. $\Delta L/L_0$ and draw the line that best fits the values (C.4). INCLUDE THIS GRAPH IN THE ANSWER SHEET

How can you obtain the Young's Modulus from the graph? (C.5).

Obtain the Young's Modulus for nylon (C.6), in SI units, with only one significant figure.

Repeat the process for the silk thread using 50 g masses instead of 20 g. Write up the corresponding answers (C.7 - C.9) in the Answer Sheet.

Now you should have sufficient information to answer question C.10 in the Answer Sheet.

THE END

GOOD LUCK!