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Please write your **SID** legibly at the top of each page

1) **[3 points]** For each of the following items, determine whether it would be most appropriate to measure in nanometers (nm), micrometers (μm), or millimeters (mm). Circle your answers.

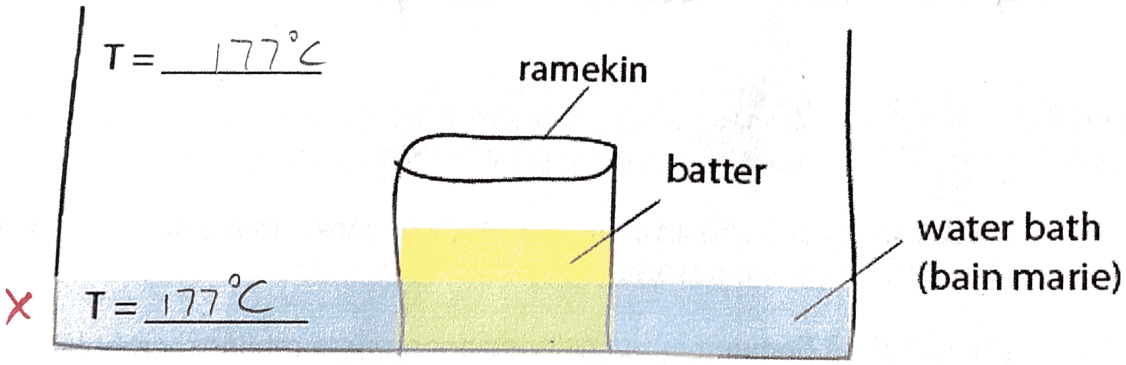
3

a. The width of a sodium ion:	(nm)	μm	mm
b. The width of a human hair:	nm	μm	(mm)
c. The surface area of a single bacterial cell:	nm^2	(μm^2)	mm^2

2) After completing PhySci7, you land a job at Thomas Keller's *French Laundry*. On your first day, you are responsible for cooking lemon pudding cakes for their brunch tasting menu using a classic *bain marie*, where the batter is placed in a ceramic cup (or ramekin) that is placed in a water bath in the oven at 350°F (or 177°C). The water bath has already been heated in the oven.

a. **[2 points]** On the drawing below, label the temperatures (in °C) of the oven and the *bain marie*.

1



X

b. **[2 points]** Describe 2 phase changes the cake batter and the *bain marie* undergo in the oven during the baking time of 30 minutes.

2

- cake batter changes from liquid state to solid state
- water bath changes from liquid state to vapor (gas state)

6

c. **[1 point]** The cake batter contains 2 eggs, which are essential for the texture of the pudding cakes. Explain how phase changes in the pudding cake occur on the molecular level.

Proteins in the eggs denatures and coagulates.
Proteins untangle themselves and binds with each other.
So proteins change from transparent to opaque.

1

d. **[2 points]** You are also responsible for preparing fried eggs on parmesan crisps for the brunch tasting menu. As discussed in class, the egg transition temperature is around 65°C. Calculate the thermal energy in kJ that is required to induce this phase change ($k_B = 1.38 \times 10^{-26}$ kJ/K).

$65°C = 65 + 175 = 240\,K$

thermal energy $= k_B T$

$= 1.38 \times 10^{-26} \times 240$

$= 3.312 \times 10^{-24}$ kJ

2

3) **[3 points]** During the first week of class, Dolores Hernandez taught us about healthful eating. For the following questions, determine if the statement is either true of false.

(True/False) You should blend your food or cook it to maximize the amount of fiber your body can absorb.

3

(True/False) The number of calories per gram of proteins, carbohydrates, and fats is described by the 4-4-9 rule.

(True/False) One serving of Omega-3 fatty acids contains 23.9 Calories; this is equivalent to 5.7 kJ of energy.

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4) While reading *On Food and Cooking*, you encountered an amazing table of common fats and oils that details the proportions of saturated and unsaturated fats.

Saturated and Unsaturated Fatty Acids in Foods and Cooking Fats

Proportions of fatty acids are given as a percentage of the total fatty-acid content.

Fat or Oil	Saturated Fatty Acids	Monounsaturated Fatty Acids	Polyunsaturated Fatty Acids
Butter	62	29	4
Beef	50	42	4
Lamb	47	42	4
Pork	40	45	11
Chicken	30	45	21
Coconut oil	86	6	2
Palm kernel oil	81	11	2
Palm oil	49	37	9
Cocoa butter	60	35	2
Vegetable shortening	31	51	14
Cottonseed oil	26	18	50
Stick margarine	19	59	18
Tub margarine	17	47	31
Peanut oil	17	46	32
Soybean oil	14	23	58
Olive oil	13	74	8
Corn oil	13	24	59
Sunflower seed oil	13	24	59
Grapeseed oil	11	16	68
Canola oil	7	55	33
Safflower oil	9	12	75
Walnut oil	9	16	70

2

a. **[4 points]** Based on your understanding of the different interaction energies between saturated and unsaturated fats, rank these substances in order of melting temperatures with the #1 ranking going to the substance with the lowest melting temperature.

2

FAT	RANK (1-4)
butter	4
palm oil	2
stick margarine	1
cocoa butter	3

b. **[1 point]** Now compare your ranked list from the previous question to the actual melting temperatures: butter T_m = 30-35 °C, cocoa butter T_m = 35 °C, stick margarine T_m = 33-35 °C, and palm oil T_m = 33-39 °C. What could be a reason for this mismatch?

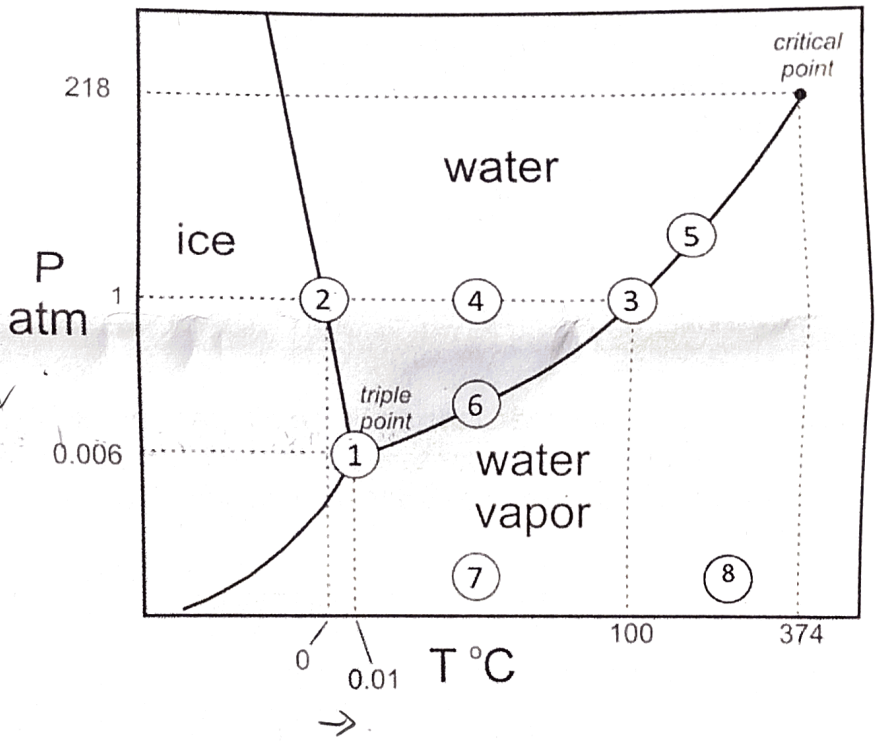
1

a. Butter is typically a solid at room temperature
b. Margarine is derived from vegetable oil
c. Melting temperature also depends on chain length
d. Palm oil has a lower pH than the other three fats

3

5) **[2 points]** Consider the phase diagram for water below. Describe how the entropy of water changes as the system goes from point #4 to point #8.

2 As water changes from liquid state to vapor, the disorder of the system increases, and entropy of water increases.



6) **[2 point]** Jim lives in Denver, Colorado. He wants to make ice cream by depressing the freezing temperature of ice to -10°C. The "Mile High City" is indeed about a mile above sea level. What advice do you give your friend? (Hint: the phase diagram above may be useful to understand how the freezing point changes with changing pressure.)

0
a. Add **more salt** to the ice bag; water freezes at a **higher temperature** in Denver
b. Add **more salt** to the ice bag; water freezes at a **lower temperature** in Denver
c. Add **less salt** to the ice bag; water freezes at a **higher temperature** in Denver
d. Add **less salt** to the ice bag; water freezes at a **lower temperature** in Denver

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7) **[1 point]** Uh-oh, Jim is out of rock salt. He digs around in the cupboards and find only a package of brown sugar and a box of baking soda. He has no choice but to add brown sugar, add baking soda or not make ice cream. What should he choose?

a. Add brown sugar
b. Add baking soda – sodium bicarbonate – a type of salt.
c. Not make ice cream.

8) In Jim's kitchen you find both **sodium chloride (NaCl)** and **calcium chloride ($CaCl_2$).** When dissolved in water, one molecule of calcium chloride becomes one calcium ion and two chloride ions.

a. **[2 points]** Calculate the freezing point depression in °C (ΔT) if Jim adds 10 g calcium chloride to 100 g of water. (Hints: K_f = 1.86 °C kg/mol, the M.W. of calcium chloride is 110.98 g/mol).

$$b_{solute} = \frac{\frac{10}{110.98}}{0.1\ kg} = 0.901\ mol/kg.$$

$$\Delta T_f = b_{solute} \times i \times K_f$$

$$= 0.901 \times 3 \times 1.86$$

$$= 5.0279\ °C$$ is the freezing point depression.

b. **[2 points]** If Jim only had sodium chloride available to him, describe how the freezing point depression would be effected if the same amount of NaCl was dissolved into the water compared to the freezing point above. Here, assume you add the same number of moles. Would sodium chloride be more or less efficient for making ice cream than calcium chloride?

Since $\Delta T_f = b_{solute} \times i \times K_f$,

we add the same amount of moles, b_{solute} and K_f don't change.

NaCl becomes Na^+ and Cl^- in water, so each molecule becomes 2 ions instead of 3 ions in the case of $CaCl_2$.

Thus, i decreases, and the value of freezing point depression decreases.

So NaCl would be less efficient for making ice cream.

+5

9) In this picture above, eggs were placed in a pickling solution along with red cabbage. Over time, the red color molecules from the cabbage moved into the eggs, causing them to be dyed pink. You scored your dream job working for Martha Stewart. She is enamored with these pink pickled eggs for the Easter issue of her magazine. Based on your PhySci7 expertise, she asks you to write the recipe.

a. **[2 points]** The key to an Instagram-ready egg is in the pickling time. If you only want the pink outline to be 5 mm thick, how many hours do you instruct readers to leave their eggs in the pink pickling solution for? (D_{dye} = 5.8 x 10^{-10} m^2/sec)

$\Delta x = \sqrt{2Dt}$

$(5 \times 10^{-3})^2 = 2 \times 58 \times 10^{-10} \times t$

$t = 21551.72\ s$

$= \frac{21551.72}{60 \times 60} = 5.99$ hours

b. **[2 points]** Include 2 tips on how you could advise readers to speed up the pickling/dying process.

1. You can speed up the pickling process by increasing the temperature of the solution.
2. You can speed up the process by decreasing the viscosity of the pickling solution.

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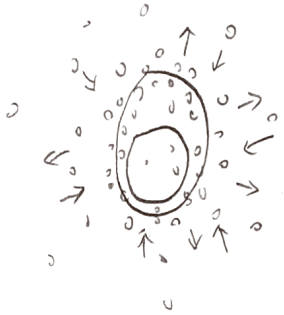
c. **[2 points]** She thinks readers will be fascinated to learn more about the science of the pickling and coloring process and encourages you to draw a schematic illustration to include with your recipe. Draw a simple picture showing: 1) the egg, 2) the concentration of dye molecules inside and outside of the egg, and 3) the direction of the flux.



→ shows directions dye molecules move in random directions

~~0.5 net flux inwards~~

10) In lab we monitored the breakdown of gelatin by enzymes in fresh pineapple juice, canned pineapple juice, and meat tenderizer.

[2 points] Which solutions contained active bromelain? Circle all that apply.

a. fresh pineapple juice
b. canned pineapple juice
c. meat tenderizer ✗ −0.5
d. control solution

[2 BONUS points] Using only the materials supplied in lab except for the fresh pineapple, what could you do to make the canned pineapple juice break down the gelatin? Explain on a molecular level how this would work to receive extra points.

Ingredients:
- water
- canned pineapple
- meat tenderizer

+3.5 ~~+3~~ +1 BONUS

Since canning process of canned pineapple puts pineapple juice under high temperature, the enzymes inside pineapple are broken. Enzymes are a special type of proteins. This means proteins denatured under the heat. It's no possible to make the denatured proteins to go back to its original form. So the only solution is to add meat tenderizer in canned pineapple and mix them together. Since meat tenderizer contains this enzyme to break down gelatin, the canned pineapple juice will contain these enzymes and break down the gelatin

pH?