1) If a 10.0 g sample of each substance below has 250 J applied to it, which substance will have the greatest increase in temperature?
a. iron (specific heat = 0.46 J/g)
b. water (specific heat = 4.184 J/g)
c. copper (specific heat = 0.39 J/g)
d. aluminum (specific heat = 0.92 J/g)
e. Not enough information to determine.

2) Of the molecules below, which ones undergo extensive hydrogen bonding?

H_2Te, H_2S, H_2O, HBr, HCl, HF, SiH_4, CH_4, HI, NH_3, PH_3, AsH_3

a. HBr, HCl, HF, H_2O
b. H_2O, HF, NH_3
c. CH_4, H_2O, HF, NH_3
d. H_2S, H_2O, HCl, HF
e. AsH_3, NH_3, HF, H_2S

3) Predict qualitatively the relative bond lengths of the four single bonds given below and arrange them from **shortest to longest**:

C-N N-O N-Si O-O

a. O-O < Si-N < C-N < N-O
b. O-O < N-O < C-N < N-Si
c. O-O < C-N < N-O < N-Si
d. N-O < O-O < C-N < N-Si
e. N-Si < C-N < N-O < O-O

4) Which bond is **most** polar?
a. C-C
b. C-N
c. N-H
d. C-F
e. C-O

5) What is the formal charge on sulfur in SO_2?
a. +2
b. +1
c. 0
d. –1
e. -2

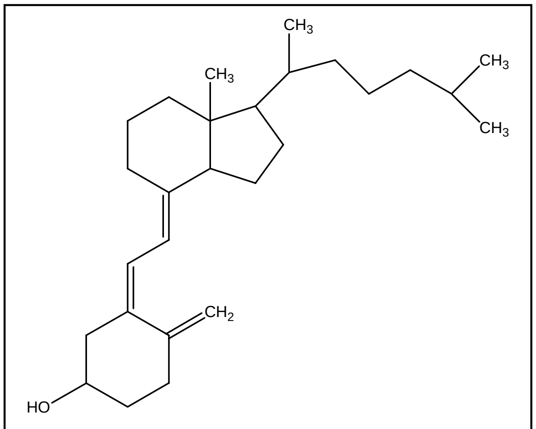
6) Which process is **exothermic**?
A. freezing rain drops
B. evaporating alcohol
C. defrosting frozen food
D. warming milk
E. subliming dry ice

7) Based on the equation below, which statement is **<u>incorrect</u>**?

$$2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(l)} \qquad \Delta H° = -\ 571.7\ kJ$$

A. The value of 571.1 kJ applies to one mole of liquid water.
B. Per half mole of O_2, ΔH° = -285.8 kJ.
C. If the state of water changes from the liquid state to the gas state, the value for ΔH° no longer applies.
D. If the equation above is divided by 2, ΔH° = - 285.8 kJ.
E. If the equation above is reversed, ΔH° = + 571.1 kJ.

8) (10 points) Bioavailability of Vitamin D
Humans need sunlight to help their bodies produce vitamin D, which helps the body absorb calcium, essential to bone growth and many other bodily functions. When ultraviolet B rays from sunlight hit the body, they strike a compound in the skin that begins a complicated process to make vitamin D. The vitamin does its crucial work in the intestines, where it aids in absorption of calcium.[1]



a) Based on the chemical structure of Vitamin D (shown on the right) would you anticipate that it would be soluble in ligroin or water? Please briefly explain.

b) Based on this chemical structure would you anticipate that absorption of Vitamin D would be highest when it is served in corn oil on toast, in whole milk, or in skim milk?

[1]Anderson, V. "Studies find Vitamin D deficiency may be more widespread; Higher recommended levels debated" The Atlanta Journal-Constitution Published on: 07/26/04

[2]Nutrition Research Newsletter, July 2003

[3]Tangprich, V.; Koutkia, P.; Rieke, S. M. Chen, T.C.; Perez, A. A.; Holick, M. F. American Journal of Clinical Nutrition 2003, 76(6) 1478-1483.

(8 cont'd)

"On three separate occasions, 18 adults ingested 25,000 IU vitamin D_2 in 240 mL whole milk or skim milk or in 0.1 mL corn oil applied to toast. Serum was obtained 0, 2, 4, 8, 12, 48, and 72 hours after ingestion of the fortified food to measure the blood concentrations of vitamin D_2."[2]

c) The results of the study are shown in Figure 1.[3] *Did the delivery method affect the concentration of serum vitamin D_2? Answer using a statement describing the results in Figure 1.*

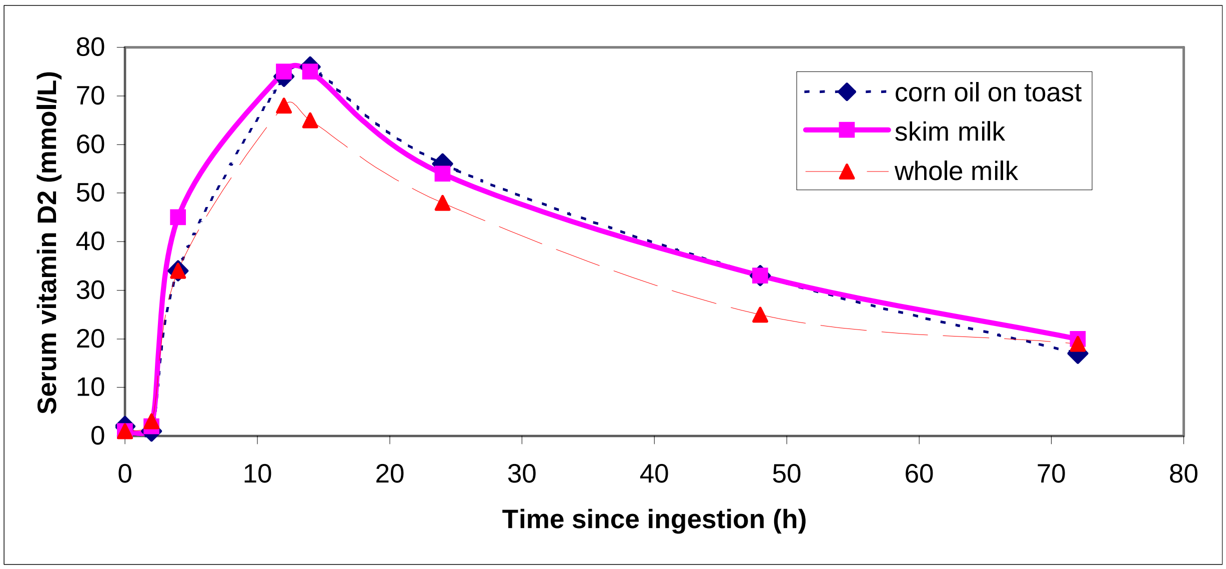


Figure 1. Serum vitamin D_2 concentrations in subjects given 25000 IU vitamin D_2 in corn oil on toast, skim milk, and whole milk; each subject ingested the 3 foods on 3 different occasions.

(8 cont'd)

Some people are not able to drink milk due to lactose intolerance, so the researchers sought another non-fat beverage to supplement with vitamin D. "One group consumed 240 mL orange juice fortified with 350 mg Ca and the other group consumed 240 mL orange juice fortified with 350 mg Ca and 1000 IU vitamin D3 (Hoffman-La Roche, Nutley, NJ) daily for 12 wk. A blood sample was obtained weekly from each subject for measurement of serum 25(OH)D."[3] The results are shown in Figure 2.[3]

"There were no significant changes in serum calcium, phosphorus, or alkaline phosphatase from baseline values in either group. None of the subjects reported any significant adverse effects. No subject developed hypercalcemia. Despite the presumed sun-induced synthesis of vitamin D in the control group, 25% of the subjects had vitamin D insufficiency at the end of the study, whereas none of the subjects who ingested 1000 IU vitamin D3 had vitamin D insufficiency."[3]

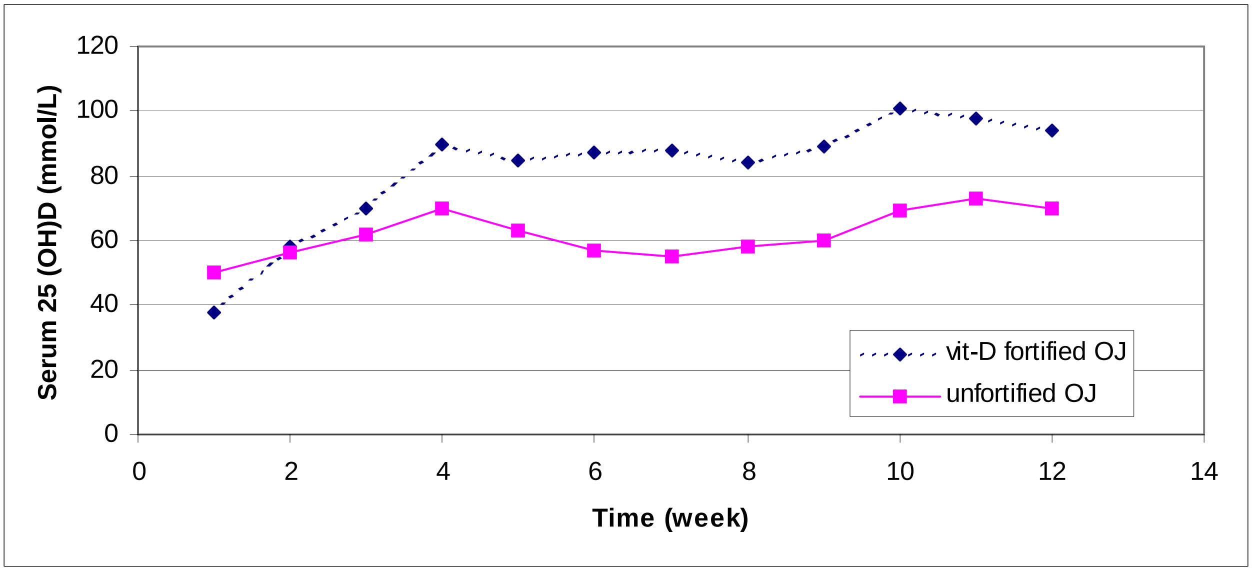


Figure 2. Average serum 25-hydroxyvitamin D[25(OH)D] concentrations in subjects who ingested vitamin D-fortified and unfortified orange juice.

d) Based on these results, would you recommend vitamin D fortified orange juice as a means of obtaining supplemental Vitamin D? Please explain.

9) (14 points) In an article from the Associated Press, printed in the Ann Arbor News (8/27/2004), the use of aluminum bottles are tauted, "The brewery has partnered with Alcoa, Inc., the world's largest aluminum maker, to produce aluminum bottles that keep beer colder for as much as 50 minutes longer than a glass bottle." "The bottles have three times the aluminum of a typical beer can. That gives them superior insulation," Alcoa spokesman Kevin Lowery said.

You wonder about the claims in the article and decide to approach the problem using your knowledge of thermochemistry. Doing some background research, you discover that the aluminum bottles are 16 oz, while the glass bottles are 22 oz. You decide to take a piece of aluminum or glass (equivalent in mass to their respective bottles) and cool it to 5°C. Then you put this piece of cooled aluminum or glass into a volume of beer (again, a volume appropriate to the size of the bottle) that is at 25°C. *Estimate the final temperature of the beer.* Work under the assumption that beer is 5% by volume ethanol and 95% water.

Aluminum

A 16 oz aluminum bottle has 3* the aluminum of a can and holds 16 oz (473. 12 mL) of beer
A 16oz aluminum can weighs 21.26 g
Heat capacity of aluminum: 0.897 J/(g ^{o}C)

Heat capacity of water: 4.184 J/(g ^{o}C)
Heat capacity of ethanol: 2.3 J/(g ^{o}C)
Ethanol has a density of 0.789 g/mL

a) T_f =

Glass

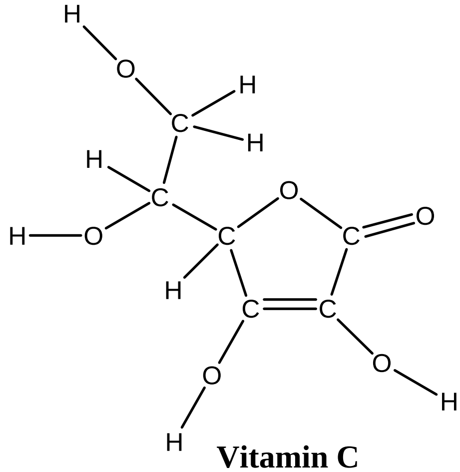
A 22 oz glass beer bottle weighs 340 g and holds 22 oz (650.54 mL) of beer.
Heat capacity of glass: 0.84 J/(g ^{o}C)

b) T_f =

Heat capacity of water: 4.184 J/gK
Heat capacity of ethanol: 2.3 J/gK
Beer averages 5% ethanol

c) Does your "experiment" support the claim that aluminum will keep beer colder for longer? Please briefly explain. (2 points)

10) (6 points)A friend needs to know the ΔH_f of vitamin C for a homework problem, but she can't find it in any of the tables in her book. Help her estimate it using bond enthalpies

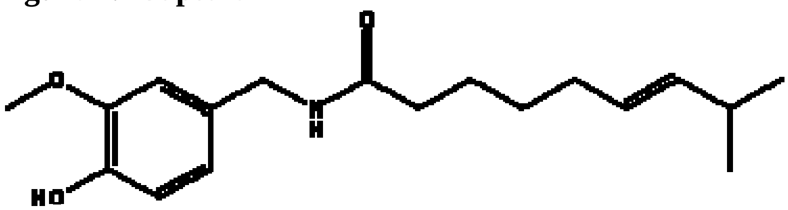


Vitamin C

Average Bond Enthalpies (kJ/mol)							
Single Bonds						***Multiple Bonds***	
H—H	436	N—H	391	I—I	151	C = C	598
H—F	566	N—N	160	I—Cl	209	C ≡ C	813
H—Cl	431	N—F	272	I—Br	180	O = O	498
H—Br	366	N—Cl	193			C = O*	695
H—I	299	N—O	201	S—H	347	C ≡ O	1073
				S—F	326	N = N	418
C—H	416	O—H	467	S—Cl	255	N ≡ N	946
C—C	356	O—O	146	S—Br	213	C ≡ N	866
C—N	285	O—F	190	S—S	226	C = N	616
C—O	336	O—Cl	205				
C—F	486	O—I	201	Si—Si	226		
C—Cl	327			Si—H	234		
C—Br	285	F—F	154	Si—C	301		
C—I	213	F—Cl	253	Si—O	368		
C—S	272	F—Br	237				
		Cl—Cl	239				
		Cl—Br	218				
		Br—Br	193				
*C = O (CO_2) = 803							

11) (*1 point*) Capsaicin (shown in Figure 1) is one of the ingredients that puts the heat into chili peppers. It stimulates nerve endings that detect pain in the mouth and elsewhere. Will drinking water after eating chili peppers help *dissolve* the capsaicin and remove it from your mouth? Explain your reasoning.

Figure 1: Capsaicin



12) (*6 points*) You want to freeze a block of water for use in an ice sculpture contest. You put 15.5 L of water at 21.3°C into a deep freezer at –22.3°C.

Heat capacities: Water: 4.184 J/g°C Ice: 2.05 J/g°C
Enthalpy of fusion of water: 333 J/g
Density of water = 1.00 g/mL

How much heat energy does the freezer remove from the water as it cools it to ice at –22.3°C?

This amount of energy is equivalent to the energy given off by burning how many grams of propane according to the equation: $C_3H_{8(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)}$ (*note, equation not necessarily balanced*)

13) (*4 points*) One method for producing H_2 on a large scale is this chemical cycle:

Step 1: $SO_{2(g)} + 2H_2O_{(g)} + Br_{2(g)} \rightarrow H_2SO_{4(l)} + 2\ HBr_{(g)}$ $\Delta H = -106.323$ kJ

Step 2: $H_2SO_{4(l)} \rightarrow H_2O_{(g)} + SO_{2(g)} + ½\ O_{2(g)}$ $\Delta H = 275.341$ kJ

Step 3: $2HBr_{(g)} \rightarrow H_{2(g)} + Br_{2(g)}$

a) What is the ΔH for the chemical reaction in step 3?

b) What is the equation for the overall process?

c) What is the ΔH of the chemical equation in b?

d) Is the overall process endothermic or exothermic?

14) The following questions concern the determination of the concentration of arsenic.

a) (*1 point*) The MCL of arsenic is 10 μg/L.
What is this in ppm?

What is this concentration in molarity?

b) (*1point)* You need a standard solution that is 0.002 M in arsenic. Describe how you would prepare 100 mL of this solution using Na_3AsO_3, a balance, and a 100 mL volumetric flask. (*Note: the solution is 0.002 M in arsenic, not sodium arsenate.)*

c) (*2 points*) A technique called AA (atomic absorption) is used to determine the concentration of arsenic in aqueous solutions. This technique is very similar to the spectroscopy that you used to determine the concentrations of nitrate for the case study. Rather than using the visible region of the electromagnetic spectrum, light of wavelength 193.6 nm is used. Beer's Law still applies. What is Beer's Law?

Describe briefly how you would use Beer's Law to determine the concentration of arsenic if you suspected that you would be testing samples near the MCL.

15) One of the latest trends in the food industry is the use of plastic bottles made of polyethylene terephthalate (PET) for packaging beer is the use of plastic bottles. Plastic is an attractive packaging because it is lighter than glass and it does not break as easily nor leave behind dangerous shards when broken. How do glass and plastic compare in thermochemical terms?

Suppose that you were to place a 6-pack of Miller Genuine Draft Beer bottled in glass at 25°C in a cooler containing an 2 lb bag of ice at 0°C and a 6-pack of Miller Genuine Draft Beer bottled in plastic at 25°C in another identical cooler containing an 2 lb bag of ice at 0°C. What is the final temperature of each cooler when it reaches thermal equilibrium? Assume that each cooler is a perfect insulator.

Beer is 4.8% ethanol; assume the rest is water.
1 oz = 29.574 mL
1 lb = 453.6 g
Heat capacities:

Water	4.184 J/g°C
Ethanol	2.4 J/g°C
Glass	0.84 J/g°C
PET	1.25 J/g°C
Ice	2.05 J/g°C

Heat of fusion of water: 333 J/g
Densities:

Water	1.0 g/mL
Ethanol	0.789 g/mL

Glass

Final temperature
Is there ice left?

Miller uses 22oz glass bottles that weigh 340g.

Plastic

Final temperature: : 3.63°C
Is there ice left? no

Miller uses 20 oz plastic bottles that weigh 43g.

Once cooled to the same temperature, will the beer in a glass or a plastic bottle taken from the cooler start to warm up sooner? Explain

16) **Background**

Both phosphorus and nitrogen are essential nutrients for the plants and animals that make up the aquatic food web. Since phosphorus is the nutrient in short supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable events in a stream including accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals.

Sources of phosphorus include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, drained wetlands, water treatment, and commercial cleaning preparations.

The EPA water quality criteria state that phosphates should not exceed 0.025 mg/L within a lake or reservoir to control algal growth (USEPA, 1986).

Phosphate levels are often tested for using the ascorbic acid method. Briefly, a reagent containing ascorbic acid and ammonium molybdate reacts with orthophosphate in the sample to form molybdenum blue (a complex oxide or mixture of oxides of Mo_2O_5 and MoO_3) with a strong blue color.

$$PO_4^{-3} + 12(NH_4)_2MoO_4 + 24H^+ \rightarrow (NH_4)_3PO_4.12MoO_3 + 21\ NH_4^+ + 12H_2O$$
$$(NH_4)_3PO_4 \cdot 12MoO_3 + Sn^{2+} \rightarrow \text{(Molybdenum Blue)} + Sn^{4+}$$

Problem

Your friends live on a lake which is experiencing an algal blooms. They would like your help in testing the phosphate concentration in the lake, so they give you three samples and want to know if they exceed 0.025 mg/L phosphate.

a) (2 points) 0.025 mg/L PO_4^{-3} = _____ ppm PO_4^{-3} = ______M PO_4^{-3}

ppm PO_4^{-3}	M PO_4^{-3}

b) (2 points) You use the ascorbic acid methods to carry out your tests, preparing standards from Na_3PO_4. First you must make up standards to make your calibration curve. To make standard solution A, you weigh out 0.1873 g Na_3PO_4 and add it to a clean, dry 1 L volumetric flask and fill to the mark. *What is the concentration of PO_4^{-3} in mg/L of this solution?*

Standard solution A mg/L PO_4^{-3}

c) (1 point) You now transfer 10 mL of standard solution A into a 1 L volumetric flask and fill to the mark with water to make standard solution B. *What is the concentration of PO_4^{-3} in mg/L of this solution?*

Standard solution B mg/L PO_4^{-3}

d) (2 points) From B you make up the solutions in Table 1. *Describe how you would make up the 0.04 mg/L PO_4^{-3} standard from solution B.*

e) (1 point) Once you make all of your standards, you have to choose a wavelength to measure the absorbance of the Molybdenum blue. (The visible spectrum ranges from 400nm (violet) – 800 nm (red)) *Circle the range of wavelengths you would use:*

400-500 nm	500-600 nm	600-700 nm

The results from your measurements are shown Table 1 and Figure 1.

Table 1: Data testing for PO_4^{-3}

mg/L PO_4^{-3}	A
blank	0.002
0.01	0.125
0.03	0.378
0.06	0.747
0.09	1.128
Sample 1	0.516
Sample 2	0.528
Sample 3	0.531

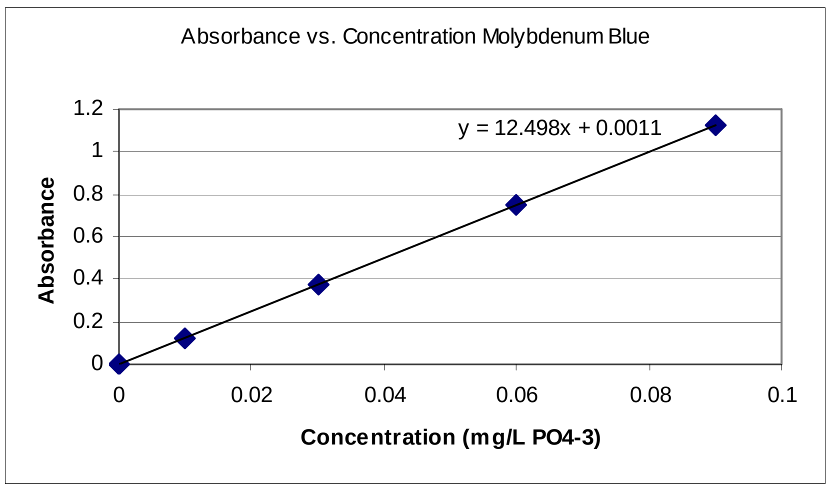


Figure 1: Calibration graph

f) (1 point) *What are the concentrations of the samples (include units):*

Sample 1

Sample 2

Sample 3

g) (1 point) *Is the level of phosphate in the lake too high?*