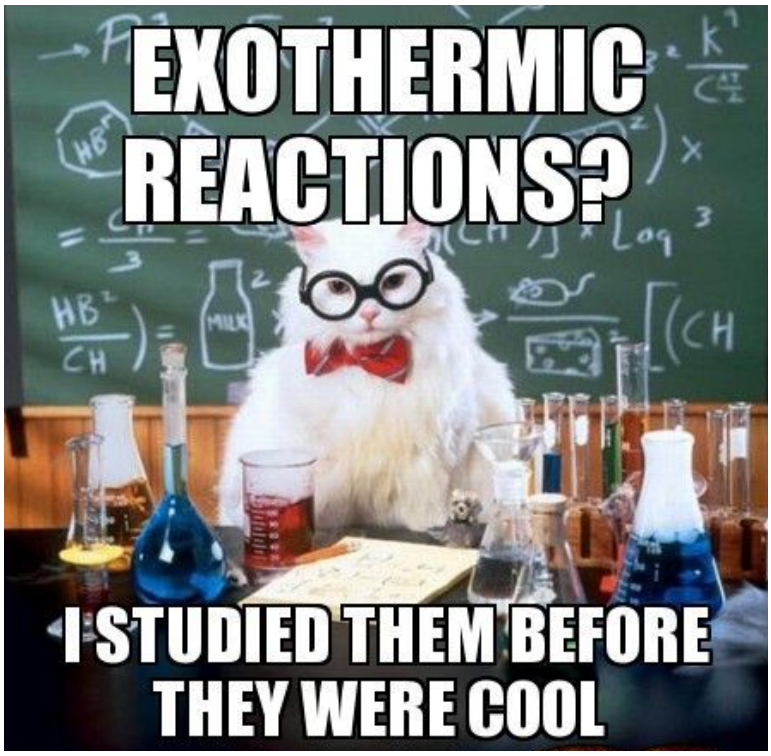
abrhsscienceteam@gmail.com Team Number: ____

2017 SSSS Chemistry Lab Test

Acton Boxborough Regional High School



School: _____

Team Members: _____ , _____

Team Number: ____

This test consists of 27 pages with reference sheets are on pages 25-27. The exam is broken into two sections: a general chemistry/physical properties part worth 100 points and a thermochemistry part worth 100 points. There is no lab portion, and there are five points of tiebreaker questions at the end of the test. The questions are not necessarily organized in increasing order of difficulty so plan accordingly.

This test is based on the draft rules for the 2017-2018 scioly season.

You are permitted to use "two **non-programmable, non-graphing calculators** and five 8.5'' x 11' sheets of paper containing information on both sides in any form and from any source. [...] **Students must wear goggles**, an apron, or a lab coat and have skin covered from the neck down to the wrist and toes" (2018 Draft Rules).

The time limit is 50 minutes---no more, no less. Good luck!

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Acton Boxborough 2017 SSSS Chemistry Lab Acton Boxborough: General Principles of Chemistry and Physical Properties (100 points) - by Allen Wang

Multiple Choice (1 point each, 15 points total)

____ 1) At STP, which halogen is a liquid?

a. F_2
b. Cl_2
c. Br_2
d. I_2

____ 2) Which of the following is blue?

a. $CuSO_{4(s)}$
b. Cu
c. $CuCO_3$
d. $CuSO_4(H_2O)_{5(s)}$

____ 3) Which of the following properties is not a physical property?

a. heat capacity
b. flame color
c. plasticity
d. luminescence

____ 4) Which of the following conducts electricity in its pure form?

a. Al
b. Si
c. Ge
d. Sb

____ 5) Small amounts of precipitate form when $CaCl_{2(aq)}$ reacts with:

a. $LiNO_{3(aq)}$
b. $NH_4OH_{(aq)}$
c. $KClO_{3(aq)}$
d. none of the above

____ 6) All of the following properties are intensive except:

a. molality
b. heat capacity
c. standard reduction potential
d. conductivity

____ 7) The SI unit for electrical resistance is:

a. ohm
b. siemens
c. coulomb
d. siemens per meter

____ 8) When 46.0 g of C_2H_5OH is combusted at SATP, all of the heat evolved is absorbed by the bomb calorimeter. If the temperature of the calorimeter increases by five degrees, what is its heat capacity?

a. 55.6 kJ/K
b. 111 kJ/K
c. 55600 kJ/K
d. 111000 kJ/K

____ 9) Ohm's law states that:

a. to obtain maximum external power from a source with a finite internal resistance, the resistance of the load and the source are equal
b. the Lorentz force is the cross product of the velocity vector and the magnetic field vector
c. the equivalent voltage V_{th} is the voltage obtained at terminals A-B of the network with terminals A-B open circuited
d. the current through a conductor between two points is directly proportional to the voltage across the two points.

____ 10) Which of the following objects is expected to have the lowest electrical resistance?

a. a 1 km overhead power line
b. a 1 m of copper wire with 1 mm diameter
c. an AA battery
d. a human body

____ 11) Which of the following reactions of solutions will always produce a precipitate?

a. $NaOH + BaBr_2$
b. $AgNO_3 + NaCl$
c. $NH_4Cl + H_2SO_4$
d. none of the reactions above yield a precipitate

____ 12) Young's Modulus is:

a. a measure of strain over stress
b. a test for plasticity
c. also known as the elastic modulus
d. a measure of geometric stiffness

____ 13) Which kind of hybridization is used in the hardest allotrope of carbon?

a. sp
b. sp^2
c. sp^3
d. no hybridization is used

____ 14) Which type of magnetism appears in all elements?

a. ferromagnetism
b. superparamagnetism
c. paramagnetism
d. diamagnetism

____ 15) Which of the following elements are deflected by a magnetic field?

I. N_2
II. O_2
III. F_2

a. II only
b. I and II only
c. I and III only
d. none are deflected

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Open Response and Calculations (85 points total)

1) Write each set of compounds in increasing order of melting points. Explain.

a) H_2O, H_2S, H_2Se. (1 point)

b) CO_2, SiO_2, GeO_2. (1 point)

c) He, Li, Al, Ga, Br_2. (3 points)

2) Define each of the following terms and give their corresponding SI unit (if applicable):

a) Electrical conductivity and SI unit. (2 points)

b) Electrical resistance and SI unit. (2 points)

c) Brittleness (1 point)

d) Paramagnetism. (1 point)

e) Magnetism. (1 point)

f) Diamagnetism. (1 point)

g) Color. (2 points)

3) $Ca(OH)_2$ is dissolved in 1.0 L of water at STP. The equilibrium concentration of OH^- was measured at 0.0222 molal. Assume that the volume taken up by $Ca(OH)_2$ is negligible.

a) Calculate the K_{sp} of $Ca(OH)_2$. (5 points)

b) Using your answer from part a, calculate the pH of a solution of a 50.0 gram solution of $Ca(OH)_2$ dissolved in 1.5 L of water at STP. (4 points)

c) What color will the solution from part b be when phenolphthalein is added? (1 point)

4) A 3.00 cm by 4.00 cm by 5.00 cm rectangular prism of aluminum falls from a 2017 ft building on Earth and hits the ground with a force of 1.59 N.

a) Calculate the density of the aluminum block in g/cm^3. (4 points)

b) Another way to calculate density is to use crystal structure. In an FCC (cubic) arranged aluminum, there are exactly 4 atoms per unit cell, and the length of a unit cell is 404 pm. Calculate the theoretical density of aluminum in g/cm^3. (5 points)

c) Convert your answer from part b to lb/in^3. (1 point)

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5) A molecule X has a vapor pressure of 213 torr at 104 ºF and ΔH_{vap} = 31.4 kJ/mole. Calculate the normal boiling point of X in Kelvin. (10 points)

6) Consider the compounds $CaCl_2$, $C_{12}H_{22}O_{11}$, Zr, Cu, Si, NH_3 at STP.

a) Which compound(s) exist as gases at STP. (1 point)

b) Order the solids in increasing order of brittleness. (2 points)

c) Order the solids in increasing order of conductivity. (2 points)

d) Order $CaCl_2$, $C_{12}H_{22}O_{11}$, and NH_3 decreasing order of molar solubility in water at STP. (2 points)

e) Which of the compounds in part d changes the boiling point of water the most when dissolved? Explain. (1 point)

f) What is the freezing point of water when a 1.000 kg solution is prepared containing 25 grams of the compound from part e at 1 atm? (3 points)

g) Which compound from part d produces the most basic solution when dissolved in water? Write the chemical equation of its reaction with H_2O. (1 point)

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7) Write the chemical formula when names are given, and write the IUPAC name when chemical formulas are given. (½ point each, 8 points total)

a) Sodium Carbonate

b) Calcium Nitrite

c) Sulfurous Acid

d) Mercury(I) Oxide

e) Lead(IV) Dichromate

f) Copper(II) Sulfate Pentahydrate

g) Cyclopropane

h) Tetraphosphorus Decaoxide

i) $AgNO_3$

j) $FeBr_2$

k) C_2H_6

l) $HC_2H_3O_2$

m) NaH_2PO_4

n) NH_4MnO_4

o) CoS_2O_3

p) SO_3

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8) The concentration of ethanol in aqueous solutions can be determined by reacting it with potassium dichromate in acid to produce ethanoic acid and Cr^{3+} ions.

a. Write a balanced equation for this reaction. (3 points)

b. Describe the color change observed during this reaction. (3 points)

c. A standard solution of $K_2Cr_2O_7$ is prepared in the following manner: 125 mL of H_2O is placed in a 250. mL volumetric flask 70. mL of concentrated H_2SO_4 is added while swirling and cooling under running water 0.750 g of dried $K_2Cr_2O_7$ is added and the solution is diluted to the mark on the neck of the flask with H_2O. Calculate the $[Cr_2O_7^{2-}]$ in the 250. mL solution. (3 points)

d. 0.600 mL of a popular mouthwash is diluted to 100. mL with H_2O. When a 10.0 mL aliquot of this solution is titrated with the solution of $K_2Cr_2O_7$ prepared in part c, 20.25 mL of $K_2Cr_2O_7$ are required. Calculate the number of moles of ethanol in 0.600 mL of mouthwash. (6 points)

e) Using the information from part d, determine the mass percentage of ethanol in this mouthwash (Assume the density of mouthwash to be 0.966 g/cm^3). (5 points)

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2017 SSSS Chemistry Lab Acton Boxborough: Thermochemistry (100 points) - by Chris Wang

Multiple Choice (1 point each, 15 points total)

____ 1) Which of the following substances has the highest entropy at constant conditions?

a. $H_2O_{(l)}$
b. $NH_{3(g)}$
c. $C_2H_{4(g)}$
d. $C_4H_{10(g)}$

____ 2) The energy released by a chemical reaction originates from:

a. intermolecular forces
b. intramolecular forces
c. increasing particle motion
d. activation energy

____ 3) The SI unit for heat is the:

a. joule
b. kilojoule
c. calorie
d. kilocalorie

____ 4) Which type of heat transfer increases the temperature of the sidewalk on a hot day?

a. conduction
b. radiation
c. convection
d. all of the above

____ 5) Which type of heat transfer causes the circular motion of air rising and sinking in the Earth's atmosphere?

a. conduction
b. radiation
c. convection
d. none of the above

____ 6) Which of the following properties changes as pressure is adjusted?

a. critical point
b. triple point
c. freezing point
d. standard heat of formation

____ 7) A substance with a positive standard heat of formation:

a. requires high energy to react
b. is susceptible to decomposition
c. tends to undergo synthesis reactions
d. can be found commonly in nature

____ 8) The phase change of a substance with the lowest value for ΔH is:

a. fusion
b. vaporization
c. sublimation
d. deposition

____ 9) A state function is a property whose value is independent of the path taken to reach that value. Which of the following is stated by Hess's Law to be a state function?

a. entropy
b. enthalpy
c. Gibbs' free energy
d. temperature

____ 10) While a substance is undergoing fusion, all of the following values are expected to change except:

a. entropy
b. enthalpy
c. Gibbs' free energy
d. temperature

____ 11) Pentane is a hydrocarbon with a vapor pressure of 57.90 kPa at STP. If its temperature is kept constant, it can be described as:

a. a liquid that will boil when altitude increases
b. a liquid that will boil when altitude decreases
c. a gas that will condense when altitude increases
d. a gas that will condense when altitude decreases

____ 12) When a substance is at its triple point, all three states of matter:

a. exist at the same time
b. are visually indistinguishable
c. have the same physical properties
d. all of the above

____ 13) A substance is heated from 20.0 ˚C to 84.9 ˚C. If another substance with the same mass and a specific heat capacity three times as great absorbs the same amount of heat, what is its final temperature?

a. 21.6 ˚C
b. 28.3 ˚C
c. 41.6 ˚C
d. 215 ˚C

____ 14) How much heat is transferred when 165.3 g of potassium chlorate decomposes according to the following chemical equation?

$2KClO_3 \rightarrow 2KCl + 3O_2 \qquad \Delta H^\circ = -90.56\ kJ$

a. 61.13 kJ
b. 100.4 kJ
c. 122.3 kJ
d. 244.5 kJ

____ 15) ΔS° is positive for which of the following equations?

I. $CO_{2(s)} \rightarrow CO_{2(g)}$
II. $HCl_{(l)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$
III. $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$

a. I only
b. II only
c. I and II only
d. I, II, and III

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Open Response and Calculations (85 points total)

1) In an interview, undersea explorer Jacques Cousteau said, "The Antarctic is the vast source of cold on our planet, just as the sun is the source of our heat, and it exerts tremendous control on our climate. The cold ocean water around Antarctica flows north to mix with warmer water from the tropics, and its upwellings help to cool both the surface water and our atmosphere."

Using the principles of thermodynamics to support your answer, identify the error in Cousteau's explanation and then restate it so that it is scientifically accurate. (4 points)

2) To market a popcorn product, a food company released a statement saying, "This new and improved popcorn with reduced-fat butter contains only 125 Calories and 5 grams of fat per ounce (28.35 grams)." To test this claim, a 3.50 g sample is combusted in a coffee cup calorimeter containing 260. g of water at 20.0 ˚C, raising the temperature of the water to 85.9 ˚C. Carbohydrates and proteins contain 16.7 kJ/g and fats contain 37.7 kJ/g. Assume that no other substances are present in the popcorn.

a) Using the calorimetric data, calculate the amount of heat in Calories per ounce of popcorn. Is the company correct in saying that there are only 125 Calories per ounce? (4 points)

b) Calculate the amount of fat in grams per ounce of popcorn. Is the company correct in saying that there are only 5 grams of fat per ounce? (4 points)

c) Explain where the popcorn's energy was initially located and how the combustion converted it to heat. What might be characteristic of high-energy substances, such as fats, that causes them to contain more energy per gram than other substances like carbohydrates and proteins? (4 points)

d) Name one source of error in the combustion that would require an improvement in the experiment. Does this mean that the true number of calories is higher or lower than your answer in part (a)? (3 points)

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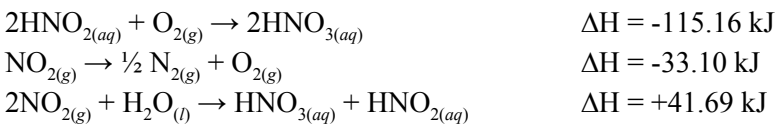
3) For each of the following processes, calculate ΔG˚. Then state whether each process is endothermic or exothermic and spontaneous or nonspontaneous. Assume conditions are kept constant at 25 ˚C and 1 atm.

a) Carbon (diamond) + Chlorine gas → Carbon tetrachloride (3 points)
(S˚ of carbon tetrachloride = 309.65 J/mol*K)

b) Calcium carbonate + Sulfuric acid → Water + Gaseous carbon dioxide + Calcium sulfate (4 points)
(S˚ of sulfuric acid = 156.9 J/mol*K; S˚ of calcium sulfate = 106.5 J/mol*K)

c) Liquid carbon disulfide → Gaseous carbon disulfide (3 points)
(S˚ of liquid carbon disulfide = 151.0 J/mol*K; S˚ of gaseous carbon disulfide = 237.98 J/mol*K)

4) While acid rain is commonly attributed to the formation of sulfuric acid, the formation of nitric acid also contributes to the issue. The following thermochemical equations represent some of the reactions that nitrogen-containing compounds tend to undergo:

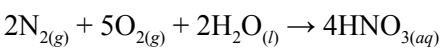


$2HNO_{2(aq)} + O_{2(g)} \rightarrow 2HNO_{3(aq)}$ $\Delta H = -115.16$ kJ

$NO_{2(g)} \rightarrow \frac{1}{2} N_{2(g)} + O_{2(g)}$ $\Delta H = -33.10$ kJ

$2NO_{2(g)} + H_2O_{(l)} \rightarrow HNO_{3(aq)} + HNO_{2(aq)}$ $\Delta H = +41.69$ kJ

The overall formation of nitric acid dissolved in rainwater is illustrated by the chemical equation below:



$$2N_{2(g)} + 5O_{2(g)} + 2H_2O_{(l)} \rightarrow 4HNO_{3(aq)}$$

a) Calculate ΔH for the equation above. (4 points)

b) How many grams of nitric acid are formed if there is a net transfer of 81.0 J over the overall process? (3 points)

5) Benzene (C_6H_6) is an insoluble hydrocarbon. 12.80 g of solid benzene at -15.810 ˚C is placed into a container holding 156.0 g of water at 21.495 ˚C. While in the water, the benzene melts into a liquid. The final equilibrium temperature of the system is 17.962 ˚C. The properties of benzene are listed below:

T_{boil} = 80.1 ˚C	ΔH_{fus} = 9.866 kJ/mol	ΔH_{vap} = 30.77 kJ/mol
C_p (*s*) = 118.4 J/mol*˚C	C_p (*l*) = 134.8 J/mol*˚C	C_p (*g*) = 82.44 J/mol*˚C

a) Determine the melting point (T_{fus}) of benzene. Assume that negligible heat is lost to the surroundings. (5 points)

b) Draw the heating curve for benzene. Label the three states of matter, all possible phase changes, and the melting and boiling points. (5 points)

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c) A 41.05 g sample of solid benzene, also at -15.810 ˚C, is placed into a container with 27.18 moles of water. Assuming that negligible heat is lost to the surroundings, what minimum initial temperature of water is needed to completely boil the benzene? (5 points)

6) Using standard values from your tables, approximate the boiling point of bromine in Celsius at 1 atm. (Hint: how is the process of $Br_{2(l)} \rightarrow Br_{2(g)}$ different above and below the boiling point?) (5 points)

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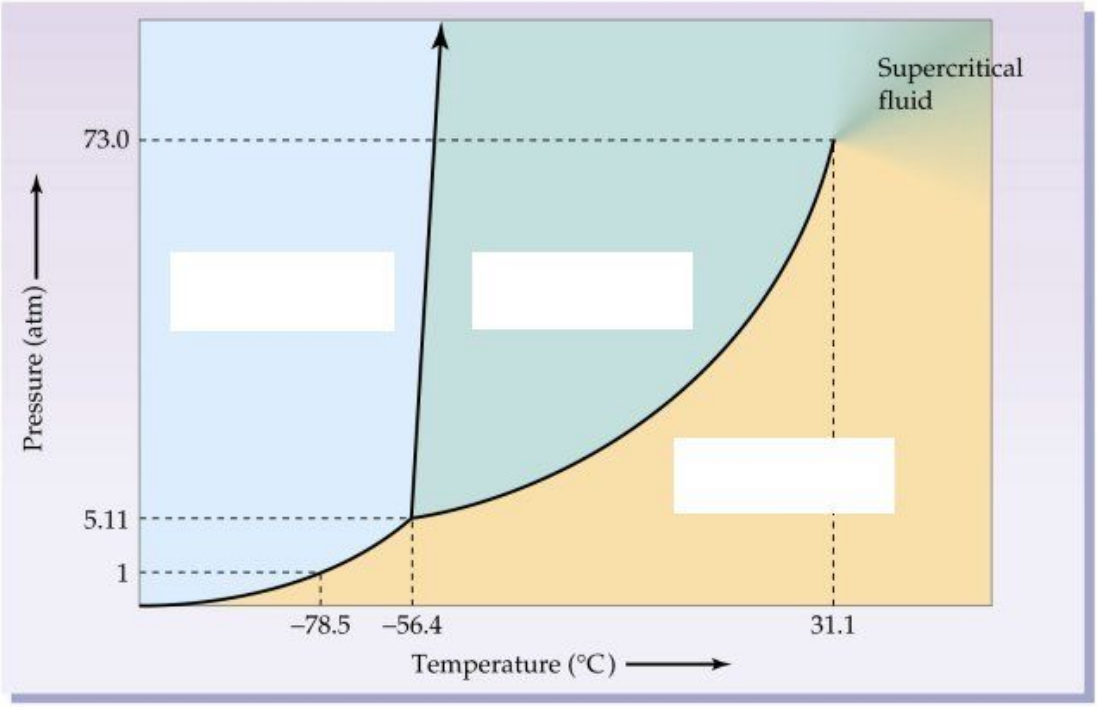
7) The following image is a phase diagram for an unknown substance:



a) Fill in the missing states of matter in the diagram. (1 point)

b) Assuming standard pressure throughout, if the solid form is placed in a room that has a temperature of 25.0 ˚C, the substance will (1 point):

c) The deposition point of the substance at -56.4 ˚C is (1 point):

d) The point marked at 31.1 ˚C and 73.0 atm is called (1 point):

e) What are two ways to condense a sample of the gas at 27.2 ˚C and 6.22 atm? (1 point)

8) The combustion of an unknown liquid hydrocarbon, C_xH_y, has a ΔH° of -4294 kJ/mol of C_xH_y. As an experiment, 34.27 g of the hydrocarbon is combusted with excess oxygen:

$$C_xH_{y(l)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)} \qquad \text{(unbalanced)}$$

11.14% of the produced gaseous carbon dioxide is induced to react with some of the produced water vapor to form 16.88 g of carbonic acid:

$$CO_{2(g)} + H_2O_{(g)} \rightarrow H_2CO_{3(aq)}$$

The remaining water vapor is electrolyzed into hydrogen gas and oxygen gas:

$$2H_2O_{(g)} \rightarrow 2H_{2(g)} + O_{2(g)}$$

The net result is illustrated by the following overall equation:

$$C_xH_{y(l)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2CO_{3(aq)} + H_{2(g)} \qquad \text{(unbalanced)}$$

There is a net loss of 990.6 kJ as heat (total, not per mole) over the experiment. Conditions are constant at 25 ˚C and standard pressure throughout. Calculate the molecular formula of the hydrocarbon. (10 points)

9) A scientist plans to react sodium sulfide and hydrochloric acid in solution. He dissolves 9.15 g of sodium sulfide in an insulated container holding 75.0 mL of water at a temperature of 25.0 ˚C. He then adds 90.0 mL of 3 M hydrochloric acid with a temperature of 20.0 ˚C and lets the reaction occur. At equilibrium, the final temperature of the water is 58.4 ˚C. Assume no heat is lost to the surroundings, the density of water is exactly 1 g/cm^3, and the solution is treated as pure water throughout. (1 M = 1 mol/L)

a) The dissolution of sodium sulfide has a ΔH of -63.5 kJ/mol. Calculate the water temperature immediately after the sodium sulfide is dissolved, but before the hydrochloric acid is added. (3 points)

b) Calculate the amount of heat, in kJ, released during the experiment by the reaction. (Hint: what would the equilibrium temperature of the water be without the reaction?) (6 points)

c) Write the thermochemical equation of the double displacement reaction in two ways. Note that one of the reactants is left in excess. (5 points)

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Tie breakers (5 bonus points total)

1) The following passage is taken from a novel:

> "Scrutiny's not really our thing," says Christina.
> "Then how do you make things better?" the little girl asks.
> "We don't, really," Christina says, sighing. "They kind of just keep getting worse."
> The little girl nods. "Entropy."
> "What?"
> "Entropy," she chirps. "It's the theory that all matter in the universe is gradually moving toward the same temperature. Also known as 'heat death.'"
> "Elia," Cara says, "that is a gross oversimplification."

a) What is the name of the thermodynamic principle on which the concept of "heat death," also known as maximum entropy, is based? (1 bonus point)

2) In the phase diagrams for some substances, such as water, the boundary between the solid state and the liquid state has a negative slope. However, for most other substances, the boundary has a positive slope. What is characteristic about the substances for which it has a negative slope? (1 bonus point)

3) What substance is depicted in the phase diagram in Open Response #7? (1 bonus point)

4) What is the sum of the coefficients when the following equation is balanced? (2 bonus point)

$$K_4[Fe(SCN)_6] + K_2Cr_2O_7 + H_2SO_4 \rightarrow Fe_2(SO_4)_3 + Cr_2(SO_4)_3 + CO_2 + H_2O + K_2SO_4 + KNO_3$$

Table 6.1. Standard heats of formation of some substances at 25 °C and 1 atm

Substance	ΔH_f° (kJ/mol)	Substance	ΔH_f° (kJ/mol)	Substance	ΔH_f° (kJ/m
$Al(s)$	0	$HCHO_2(g)$ (formic acid)	−363	$LiCl(s)$	−408.8
$AlCl_3(s)$	−704	$HC_2H_3O_2(l)$ (acetic acid)	−487.0	$Mg(s)$	0
$Al_2O_3(s)$	−1676	$HCHO(g)$ (formaldehyde)	−108.6	$MgCl_2(s)$	−641.8
$Al_2(SO_4)_3(s)$	−3441	$CH_3CHO(g)$ (acetaldehyde)	−167	$MgCl_2 \cdot 2H_2O(s)$	−1280
$As(s)$	0	$(CH_3)_2CO(l)$ (acetone)	−248.1	$Mg(OH)_2(s)$	−924.7
$AsH_3(g)$	+66.4	$C_6H_5CO_2H(s)$ (benzoic acid)	−385.1	$KMnO_4(s)$	−813.4
$As_4O_6(s)$	−1314	$CO(NH_2)_2(s)$ (urea)	−333.5	$MnSO_4(s)$	−1064
$As_2O_5(s)$	−925	$Cl_2(g)$	0	$N_2(g)$	0
$Ba(s)$	0	$HCl(g)$	−92.5	$NH_3(g)$	−46.0
$BaCO_3(s)$	−1219	$HCl(aq)$	−167.2	$NH_4Cl(s)$	−314.4
$BaCl_2(s)$	−860.2	$Cr_2O_3(s)$	−1141	$NO(g)$	+90.4
$Ba(OH)_2$	−998.22	$(NH_4)_2Cr_2O_7(s)$	−1807	$NO_2(g)$	+34
$BaSO_4(s)$	−1465	$K_2Cr_2O_7(s)$	−2033.01	$N_2O(g)$	+81.5
$Br_2(l)$	0	$Cu(s)$	0	$HNO_3(l)$	−174.1
$Br_2(g)$	+30.9	$CuCl_2(s)$	−172	$O_2(g)$	0
$HBr(g)$	−36	$CuO(s)$	−155	$O_3(g)$	+143
$Ca(s)$	0	$Cu_2S(s)$	−79.5	$P(s, \text{white})$	0
$CaCO_3(s)$	−1207	$CuS(s)$	−53.1	$P_4O_{10}(s)$	−2984
$CaCl_2(s)$	−795.8	$CuSO_4(s)$	−771.4	$H_3PO_4(s)$	−1279
$CaO(s)$	−635.5	$CuSO_4 \cdot 5H_2O(s)$	−2279.7	$K(s)$	0
$Ca(OH)_2(s)$	−986.6	$F_2(g)$	0	$KCl(s)$	−436.8
$Ca_3(PO_4)_2(s)$	−4119	$HF(g)$	−271	$SiH_4(g)$	+33
$CaSO_3(s)$	−1156	$H_2(g)$	0	$SiO_2(s, \text{alpha})$	−910.0
$CaSO_4(s)$	−1433	$H_2O(l)$	−286	$Na(s)$	0
$CaSO_4 \cdot \frac{1}{2}H_2O(s)$	−1573	$H_2O(g)$	−242	$NaF(s)$	−571
$CaSO_4 \cdot 2H_2O(s)$	−2020	$H_2O_2(l)$	−187.8	$NaCl(s)$	−413
$C(s, \text{graphite})$	0	$I_2(s)$	0	$NaBr(s)$	−360
$C(s, \text{diamond})$	+1.88	$I_2(g)$	+62.4	$NaI(s)$	−288
$CCl_4(l)$	−134	$HI(g)$	+26	$NaHCO_3(s)$	−947.7
$CO(g)$	−110	$Fe(s)$	0	$Na_2CO_3(s)$	−1131
$CO_2(g)$	−394	$Fe_2O_3(s)$	−822.2	$Na_2O_2(s)$	−504.6
$CO_2(aq)$	−413.8	$Fe_3O_4(s)$	−1118.4	$NaOH(s)$	−426.8
$H_2CO_3(aq)$	−699.65	$Pb(s)$	0	$Na_2SO_4(s)$	−1384.49
$CS_2(l)$	+89.5	$PbO(s)$	−217.3	$S(s, \text{rhombic})$	0
$CS_2(g)$	+117	$PbO_2(s)$	−277	$SO_2(g)$	−297
$CH_4(g)$	−74.9	$Pb(OH)_2(s)$	−515.9	$SO_3(g)$	−396
$C_2H_2(g)$	+227	$PbSO_4(s)$	−920.1	$H_2SO_4(l)$	−813.8
$C_2H_4(g)$	+51.9	$Li(s)$	0	$SnCl_4(l)$	−511.3
$C_2H_6(g)$	−84.5			$SnO_2(s)$	−580.7
$C_3H_8(g)$	−104			$Zn(s)$	0
$C_4H_{10}(g)$	−126			$ZnO(s)$	−348
$C_6H_6(l)$	+49.0			$ZnSO_4(s)$	−982.8
$CH_3OH(l)$	−238				
$C_2H_5OH(l)$	−278				

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Substance	S^0(J/K-mol)	Substance	S^0(J/K-mol)
$Al_2O_3(s)$	50.99	$HCl(g)$	186.7
$Br_2(g)$	245.3	$H_2S(g)$	205.6
$Br_2(l)$	152.3	$I_2(g)$	260.6
$C(s$, diamond)	2.439	$I_2(s)$	117
$C(s$, graphite)	5.694	$N_2(g)$	191.5
$CH_4(g)$	186.2	$NH_3(g)$	192.5
$CO(g)$	197.9	$NO(g)$	210.6
$CO_2(g)$	213.6	$NO_2(g)$	240.5
$CaCO_3(s)$	88.7	$Na_2CO_3(s)$	136
$CaO(s)$	39.75	$NaCl(s)$	72.4
$Cl_2(g)$	223.0	$O_2(g)$	205.0
$F_2(g)$	203	$O_3(g)$	238
$Fe(s)$	27.2	$P(s$, white)	44.4
$Fe_2O_3(s)$	90.0	$P(s$, red)	29
$H_2(g)$	130.6	$S(s$, rhombic)	31.9
$H_2O(g)$	188.7	$S(s$, monoclinic)	32.6
$H_2O(l)$	69.94	$SO_2(g)$	248.5
$H_2O_2(l)$	92	$SO_3(g)$	256.2

Substance	ΔG_f^0(kJ/mol)	Substance	ΔG_f^0(kJ/mol)	Substance	ΔG_f^0(kJ/mol)
$Al_2O_3(s)$	−1576.4	$Fe(s)$	0.0	$NO(g)$	86.69
$Br_2(g)$	3:14	$Fe_2O_3(s)$	−741.0	$NO_2(g)$	51.84
$Br_2(l)$	0.0	$H_2(g)$	0.0	$Na_2CO_3(s)$	−1048
$C(s$, diamond)	2.866	$H_2O(g)$	−288.6	$NaCl(s)$	−384.03
$C(s$; graphite)	0.0	$H_2O(l)$	−237.2	$O_2(g)$	0.0
$CH_4(g)$	−50.79	$H_2O_2(l)$	−114.0	$O_3(g)$	163.4
$CO(g)$	−137.3	$HCl(g)$	−95.27	$P(s$, white)	0.0
$CO_2(g)$	−394.4	$H_2S(g)$	−33.02	$P(s$, red)	−14
$CaCO_3(s)$	−1127.7	$I_2(g)$	19.4	$S(s$, rhombic)	0.0
$CaO(s)$	−604.2	$I_2(s)$	0.0	$S(s$, monoclinic)	0.096
$Cl_2(g)$	0.0	$N_2(g)$	0.0	$SO_2(g)$	−300.4
$F_2(g)$	0.0	$NH_3(g)$	−16.64	$SO_3(g)$	−370.4

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PERIODIC TABLE OF THE ELEMENTS

1 **H** 1.008																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.30											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.91	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 ***La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.02	89 **†Ac** 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (272)							

*Lanthanide Series	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
†Actinide Series	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

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