

Name: _____

Score: /60

Note: A Periodic Table is provided for reference at the end.

Section 1: Thermodynamics

- Which of the following is not a state function?
(a) Energy (b) Enthalpy (c) Work (d) Pressure (e) Volume (f) Helmholtz Free Energy
- At constant pressure and volume and at 300 K, a reaction has $\Delta G = 0.15$, while at 3000 K, a reaction has $\Delta G = 20$. What can we conclude about this reaction?
(a) The reaction will be spontaneous at 100K (b) There is a change in state of matter
(c) The reaction will be spontaneous at 200K (d) $\Delta H < 0$
- Which of the following elements could have a negative heat of fusion at 1 atm pressure?
(a) Hydrogen (b) Helium (c) Lithium (d) Beryllium (e) Iodine (f) Phosphorous
- A system of ideal nitrogen gas is compressed at constant temperature. What are the signs of work and heat in this compression? (W,Q) =
(a) (+,+) (b) (+,-) (c) (-,+) (d) (-,-)
- What is the high temperature limiting molar heat capacity of diatomic gases (R = gas constant)?
(b) R (c) 3R/2 (d) 2R (e) 5R/2 (f) 3R (g) 7R/2 (h) 4R (i) 9R/2 (j) 5R (k) 4R/3 (l) 8R/3
- From the definition of entropy and the second law of thermodynamics, derive the fact that spontaneous reactions will only occur when $\Delta G \leq 0$ [You may assume constant pressure]
- A calorimeter at 23°C has a heat capacity of 100 J/C° and is filled with 30.1 L of water at 30°C . Afterwards, a piece of 2.01 g iron (heat capacity: 0.45 J/(g K)) at 700°C is dropped into the calorimeter. Find the final temperature after equilibrium is established. Assume no heat is lost.
- Explain why humans can and still exist, despite the laws of thermodynamics.

9. According to the Dulong–Petit law, the molar heat capacity of many elements is $3R$, where R is the gas constant.
- (a). Calculate the molar heat capacity of iron, given that its heat capacity is 0.45 J/(g K)
- (b). Calculate the molar heat capacity of water, given that its heat capacity is 4.2 J/(g K)
- (c). Explain the cause(s) of any significant deviations from the Dulong-Petit law from parts (a) and (b). If there are no significant deviations, then do not answer this question.
10. If 1 g iron at 100 K is dissolved into a beaker with 1 g water at 200 K, then what will be the final temperature after equilibrium is established?
11. [Tiebreaker] For an ideal gas, it is well known that $C_p - C_v = nR$, where n is the moles of substance, and C_p and C_v are the molar heat capacities at constant pressure and constant volume, respectively. Given that the internal energy of an ideal gas only depends on temperature, prove the above relation between C_p and C_v .
12. [Tiebreaker] 1 mol of an ideal gas is at a temperature of 300 K, and inside of an expandable 1 L container. If the container started increasing by 1 L/sec, and temperature is kept constant throughout this expansion, then at what rate is the container's pressure changing when the container is at 10 L? Assume no loss of energy or loss of molecules.

Section 2: Physical Properties

13. A 10 mL solution of CuCl_2 in water is diluted to 1 L. If the freezing point of the first solution, before dilution, is -5.58 C , then find the freezing point of the solution after dilution.
14. Which of the following would have the highest boiling point?
(a) n-octane (b) water (c) sodium chloride (d) diamond (e) 2-propanol
15. Which of the following salts would produce a colorless solution when dissolved?
(a) $\text{Zn}(\text{NO}_3)_2$ (b) $\text{K}_2\text{Cr}_2\text{O}_7$ (c) BaSO_4 (d) CuCl_2 (e) KMnO_4 (f) NaI
16. An unknown metal is subjected to a flame test and produces a crimson red color. It is then combined with AgCl in solution and the resulting solution precipitates out Ag . Adding excess KNa_2PO_4 to this solution results in the formation of another precipitate. What is this metal?
(a) Li (b) Na (c) K (d) Au (e) Ca (f) Mg (g) Sr
17. Caesium Fluoride adopts a cubic close packed lattice structure in its crystal form, with unit cell length of 624 angstroms. Find its density.
18. Which of the following compounds, when combined together, would likely produce a non-brittle compound?
(a) $\text{NaNO}_3 + \text{KCl}$ (b) $\text{CF}_3\text{SO}_3\text{H} + \text{NaH}$ (c) $\text{Ag} + \text{Mg}(\text{OH})_2$ (d) $\text{AgNO}_3 + \text{CuCl}_2$
19. Which of the following solids would easily sublime? (circle all that apply)
(a) CO_2 (b) Naphthalene (c) I_2 (d) p-Toluenesulfonic acid
20. Which of the following liquids would have the highest dielectric constant?
(a) Benzene (b) Diethyl ether [ethoxyethane] (c) Water (d) HCl
21. Explain how a mixture of the following liquids could be separated:
Ammonia, Water, Lauric Acid (bp 300 C), Benzene

22. Explain how a mixture of iron, gold, and pulverized balsa wood can be separated.
23. Vulcanization of rubber is a common process used in order to make rubber much more elastic than natural rubber. Describe what this process does to the rubber's chemical structure.
24. Dichromate ions can be converted to chromate ions through an acid catalyst. Provide a way to qualitatively see that this change has occurred. (Be specific)
25. A solution of a non-electrolyte, x, contains 42 grams of x per kilogram of water and freezes at -1.46°C . What is the molecular weight of x?
26. A piece of silver foil has a width of 2.00 cm and is 0.00200 in. thick. If the density of silver is 10.5 g/cm^3 , how long of a strip should be cut to obtain 1.00 g of the metal?
27. Which substance is most soluble in water?
(a) glucose (b) ethanol (c) octanol (d) benzene (e) 1-methylcyclopropene

Periodic Table of Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																																																																	
1 H Hydrogen 1.00794	<table border="1"> <tr> <td>C Solid</td> <td colspan="10">Metals</td> <td colspan="5">Nonmetals</td> </tr> <tr> <td>Hg Liquid</td> <td>Alkali metals</td> <td>Alkaline earth metals</td> <td>Lanthanoids</td> <td>Transition metals</td> <td>Poor metals</td> <td>Other nonmetals</td> <td>Noble gases</td> <td colspan="10"></td> </tr> <tr> <td>H Gas</td> <td colspan="10"></td> <td colspan="5"></td> </tr> <tr> <td>Rf Unknown</td> <td colspan="10"></td> <td colspan="5"></td> </tr> </table>															C Solid	Metals										Nonmetals					Hg Liquid	Alkali metals	Alkaline earth metals	Lanthanoids	Transition metals	Poor metals	Other nonmetals	Noble gases											H Gas																Rf Unknown																2 He Helium 4.002602
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3 Li Lithium 6.941	4 Be Beryllium 9.012182																5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797																																																												
11 Na Sodium 22.98976928	12 Mg Magnesium 24.3050																13 Al Aluminum 26.9815386	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948																																																												
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.887	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.9334	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798																																																																	
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.95	43 Tc Technetium (97.9072)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293																																																																	
55 Cs Cesium 132.9054519	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.222	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98040	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)																																																																	
87 Fr Francium (223)	88 Ra Radium (226)	89-103	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Uub Ununbium (285)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (282)	117 Uus Ununseptium	118 Uuo Ununoctium (284)																																																																	

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

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57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90766	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93402	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.967
89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03688	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)