

Name \_\_\_\_\_

Circle one: Masiak, Voloschuk, Zhou, Aronson, Davenport

Write your name on this page and on the booklet (or scrap paper). The booklet is for scrap work, and will be collected but not graded. There is a 3 point penalty for not handing in the booklet.

ALL ANSWERS GO ON THE QUESTION SHEETS, NOT IN THE BOOKLET. For questions 23-37, you must show work on the question sheets (not in the booklet). The exam adds to 100 points.

This exam has 37 questions and 15 pages. Make sure you have all of them. Work quickly. Your time is limited.

$$h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s} \quad c = 3.00 \times 10^8 \text{ m/s}$$

## PERIODIC CHART OF THE ELEMENTS

IA	IIA												IIIA	IVA	VA	VIA	VIIA	0	
1 H 1.0079																		1 H 1.0079	2 He 4.0026
3 Li 6.941	4 Be 9.0122											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.179		
11 Na 22.989	12 Mg 24.305											13 Al 26.981	14 Si 28.086	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948		
19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.88	23 V 50.941	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80		
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.22	41 Nb 92.905	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29		
55 Cs 132.91	56 Ba 137.33	57 * La 138.90	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	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 226.0	89 # Ac 227.03																	

\* Lanthanides

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
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# Actinides

90 Th 232.03	91 Pa 231.03	92 U 238.03	93 Np 237.05	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (254)	100 Fm (257)	101 Md (257)	102 No (255)	103 Lr (256)
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Name \_\_\_\_\_

## Part I

For questions 1-22, put your answers on the question sheets (not in the exam booklet.) You do not have to show work on Part I.

1. (1 pt.) An element with the valence (outer) electron configuration  $3s^2 3p^4$  would most readily form an ion with what charge?
2. (1 pt.) A sample of  $O_2(g)$  is collected in a flask over water at  $26^\circ C$ . The total pressure of the gas in the flask is made equal to the air pressure in the room, which is 750 torr. The vapor pressure of  $H_2O$  at  $26^\circ C$  is 25 torr. Find the partial pressure of the  $O_2$  in the flask.
3. (3 pts.)
  - a) Give the total number of electrons in one  $NH_4^+$  ion. Count all the electrons, not just the valence electrons.)
  - b) Give the number of protons in one  $NH_4^+$  ion.
  - c) Give the number of nuclei in one  $NH_4^+$  ion.
4. (2 pts.) The valence electron configuration of  $Fe^{3+}$  is
  - a)  $3d^6 4s^2$
  - b)  $3d^3 4s^2$
  - c)  $3d^6$
  - d)  $3d^5$
  - e)  $3d^9 4s^2$

5. (2 pts.) State whether each of the following molecules has a dipole moment. Four answers are required



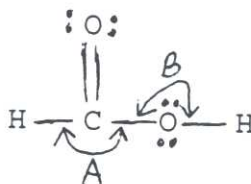
6. (1 pt.) Which one of these orbitals does not exist:

a) 4p      b) 6s      c) 3f      d) 5d      e) 2p

7. (3 pts.) Classify the bonding in each of the following as ionic, polar covalent, or nonpolar covalent. (No credit for the answer "covalent".)

a)  $\text{H}_2\text{O}$       b)  $\text{N}_2$       c)  $\text{CaO}$

8. (2 pts.) In the molecule



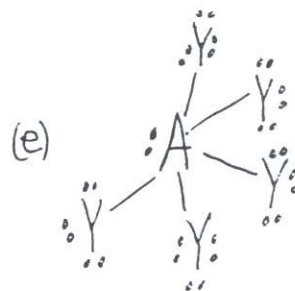
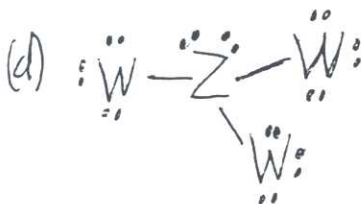
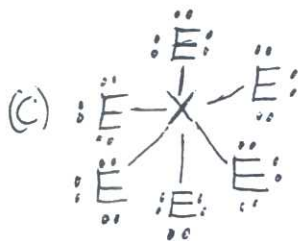
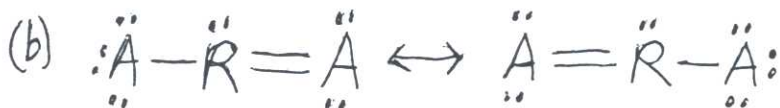
What is the value of the bond angle labeled A?

What is the value of the bond angle labeled B?

9. ( 2 pts.) Consider only the three elements S, Se, Cl.

- Which one is most nonmetallic?
- Which one has the greatest electronegativity?
- Which one has the highest ionization energy?
- Which one has the smallest atomic radius?

10. (5 pts.) For each of the following molecules, use words to describe its molecular shape (molecular geometry.) (Do not describe the electron-pair geometry.) Choose your answers from the following: Linear, bent, square planar, trigonal planar, octahedral, trigonal pyramidal, square pyramidal, trigonal bipyramidal, T-shaped, see-saw, tetrahedral, shapeless, shapely.



11. (5 pts.) For each of the molecules in question 10 give the bond angle or angles. If an angle is a bit less than a certain value, you must state this.

a)

b)

c)

d)

e)

12. (2 pts.) a) Which one of the following has the higher boiling point?  $\text{H}_2\text{O}$  or  $\text{H}_2\text{S}$
- b) Which kind of intermolecular force is responsible for the higher boiling point you picked in part (a)?
- (i) London dispersion    (ii) hydrogen bonding    (iii) dipole-dipole  
(iv) ion-dipole
13. (4 pts.) Complete and balance these reactions
- a)  $\text{Na}_2\text{O}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow$
- b)  $\text{CaCO}_3 + \text{HNO}_3(\text{aq}) \rightarrow$
- c)  $\text{Al}(\text{OH})_3(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow$
- d)  $\text{Mg}(\text{s}) + \text{O}_2(\text{g}) \rightarrow$
14. (1 pt.) Find the net ionic reaction for the following reaction
- $$2\text{CuSO}_4(\text{aq}) + \text{Mg}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow 2\text{MgSO}_4(\text{aq}) + \text{Cu}_2\text{O}(\text{s}) + \text{H}_2(\text{g})$$
15. (2 pts.) Consider only the following 1) London dispersion attractions between two small molecules, 2) the O-H bond in a water molecule, 3) hydrogen bonding between two water molecules.
- a) Which one of the three is the strongest interaction?
- b) Which one of the three is the weakest interaction?
16. (1 pt.) 185 cm is equal to
- a) 0.00185 km            b) 0.0185 km            c) 0.185 km  
d)  $185 \times 10^5$  km        e) none of these



17. (1 pt.)  $42 \text{ m}^2$  is equal to

- a)  $0.0042 \text{ cm}^2$       b)  $0.42 \text{ cm}^2$       c)  $4200 \text{ cm}^2$   
d)  $42 \times 10^4 \text{ cm}^2$       e)  $42 \times 10^6 \text{ cm}^2$

18. (6 pts.) Draw the Lewis electron dot formula of each of the following:

- a)  $\text{SF}_4$       b)  $\text{CO}_3^{2-}$       c)  $\text{C}_2\text{H}_2$       d)  $\text{H}_3\text{O}^+$

19. (1 pt.) Solid KCl is composed of

- a) atoms                      b) molecules                      c) ions.

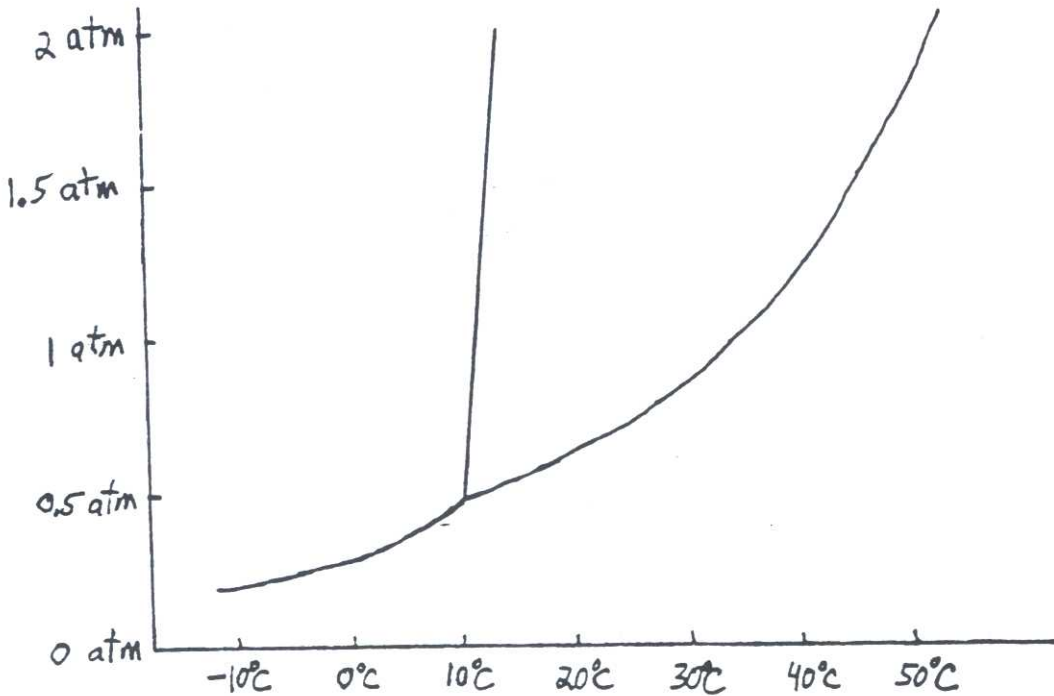
20. (4 pts.) Give the formula of each of these

- a) magnesium bicarbonate  
b) sulfurous acid  
c) iron(III) nitrite  
d) copper(II) phosphate

21. (2 pts.) Name these

- a)  $C_3O_2$   
b)  $Ag_3N$

22. (4 pts.) Consider this phase diagram for substance R:



- At 10°C and 0.1 atm, is R a solid, a liquid or a gas?
- Does the melting point of R increase, decrease, or stay the same as the pressure is increased?
- What is the vapor pressure of liquid R at 30°C. Your answers to (c) and (d) do not have to be highly precise, but should be approximately correct.
- What is the temperature of the normal boiling point of R?



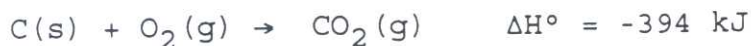
## Part II

For questions 23-37, you MUST show your work on the question sheets (NOT in the exam booklet) and you MUST choose one of the multiple choice answers. A correct answer with no work on the question sheet gets NO credit. Your work for questions 23-37 does not have to be neat. It is a waste of time to do these questions first in the answer booklet and then copy your work to the question sheets. The answer book will not be graded.

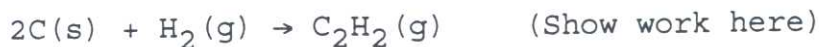
23. (3 pts.) A student adds 20.0 mL of water to an empty graduated cylinder. Then she drops 65.0 g of a solid piece of metal into the water, and the level of the top of the water rises to 35.0 mL. Find the density of the metal. Show work here (not in the exam booklet).
- a) 4.33 g/cm<sup>3</sup>
  - b) 1.86 g/cm<sup>3</sup>
  - c) 3.25 g/cm<sup>3</sup>
  - d) 1.18 g/cm<sup>3</sup>
  - e) 0.231 g/cm<sup>3</sup>
24. (3 pts.) An electron in a certain molecule has an energy of  $2.0 \times 10^{-18}$  J. If this electron absorbs a photon of frequency  $8.0 \times 10^{14}$  s<sup>-1</sup>, find the final energy of the electron. You must show work here.
- a)  $5.3 \times 10^{-19}$  J
  - b)  $2.5 \times 10^{-18}$  J
  - c)  $6.4 \times 10^{-18}$  J
  - d)  $1.1 \times 10^{-19}$  J
  - e)  $6.0 \times 10^{-23}$  J

25. (3 pts.) What mass of Zn (atomic weight 65.4 amu) will react with 280 mL of 3.00 M HCl(aq) according to  $\text{Zn} + 2\text{HCl}(\text{aq}) \rightarrow \text{ZnCl}_2(\text{aq}) + \text{H}_2(\text{g})$ . Show work here.
- a) 86.2 g
  - b) 54.9 g
  - c) 40.1 g
  - d) 27.5 g
  - e) 13.7 g
26. (3 pts.) An ideal gas at 300 K and 2.00 atm pressure in a 4000 cm<sup>3</sup> container has its pressure increased to 5.00 atm and its volume increased to 6000 cm<sup>3</sup>. What is the final temperature? Show work here.
- a) 80 K
  - b) 1125 K
  - c) 640 K
  - d) 4500 K
  - e) 820 K
- 27) (3 pts.) Find the mass in grams of one molecule of H<sub>2</sub>O. Show work here.
- a) 16 g
  - b) 18 g
  - c)  $1.08 \times 10^{25}$  g
  - d)  $1.43 \times 10^{-16}$  g
  - e)  $2.99 \times 10^{-23}$  g

28. (3 pts.) Given these  $\Delta H^\circ$  values



Find  $\Delta H^\circ$  for



- a) -3570 kJ
- b) 812 kJ
- c) 224 kJ
- d) 1918 kJ
- e) 465 kJ

29. (3 pts.) Find the number of oxygen atoms in 25 g of  $\text{CO}_2$ .

- a) 2
- b)  $9.4 \times 10^{-25}$
- c)  $6.8 \times 10^{23}$
- d)  $5.3 \times 10^{24}$
- e)  $1.2 \times 10^{23}$

30. (3 pts.) Find the empirical formula of a compound if a sample contains 3.11 g of nitrogen and 5.33 g of oxygen.  
Show work here.

- a)  $\text{N}_2\text{O}$
- b)  $\text{NO}$
- c)  $\text{NO}_2$
- d)  $\text{N}_2\text{O}_3$
- e)  $\text{N}_2\text{O}_5$

31. (3 pts.) Find the mass of  $O_2$  that will react with 22 g of  $C_3H_8$  to form  $CO_2$  and  $H_2O$ . Show work here.

- a) 20 g
- b) 40 g
- c) 80 g
- d) 120 g
- e) 160 g

32. (3 pts.) Given these bond energies in kJ/mol



estimate  $\Delta H^\circ$  for  $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$ .

Hint:  $C_2H_6$  has all single bonds. Show work here.

- a) -2831 kJ
- b) 2831 kJ
- c) -2364 kJ
- d) 2364 kJ
- e) -2548 kJ
- f) 2548 kJ

33. (3 pts.) For the reaction  $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$ , suppose 14 g of  $\text{N}_2$  and 8.0 g of  $\text{H}_2$  are present at the start of the reaction. At the end of the reaction, which one of the following will be left over (unreacted). Show work here.

- a) 3.0 g of  $\text{H}_2$
- b) 1.0 g of  $\text{N}_2$
- c) 6.0 g of  $\text{H}_2$
- d) 4.0 g of  $\text{N}_2$
- e) 5.0 g of  $\text{H}_2$
- f) 9.0 g of  $\text{N}_2$

34. (3 pts.) The vapor pressure of water at  $23^\circ\text{C}$  is 21.07 torr. Find the vapor pressure at  $23^\circ\text{C}$  of the solution formed by dissolving 15.0 g of  $\text{C}_6\text{H}_{12}\text{O}_6$  (a nonvolatile solid) in 72.0 g of  $\text{H}_2\text{O}$ . Show work here.

- a) 4.39 torr
- b) 17.44 torr
- c) 20.64 torr
- d) 21.43 torr
- e) 22.29 torr

35. (3 pts.) The specific heat of ice is  $2.09 \text{ J/g-K}$  and the specific heat of liquid water is  $4.18 \text{ J/g-K}$ . The heat of fusion of ice is  $6.01 \text{ kJ/mol}$ . Find the heat needed to convert  $36.0 \text{ g}$  of ice at  $-10^\circ\text{C}$  to liquid water at  $20^\circ\text{C}$ . Be careful with units. Show work here.

- a)  $8440 \text{ J}$
- b)  $11.8 \text{ kJ}$
- c)  $19.9 \text{ kJ}$
- d)  $15.8 \text{ kJ}$
- e)  $124.3 \text{ kJ}$

36. (3 pts.) The freezing point of  $\text{C}_6\text{H}_6$  is  $5.50^\circ\text{C}$  and  $K_f = 5.12^\circ\text{C}/(\text{mol/kg})$  for  $\text{C}_6\text{H}_6$ . A solution of  $6.42 \text{ g}$  of the nonelectrolyte compound X in  $183.2 \text{ g}$  of  $\text{C}_6\text{H}_6$  freezes at  $4.00^\circ\text{C}$ . Find the molecular weight of X. Show work here.

- a)  $288 \text{ amu}$
- b)  $207 \text{ amu}$
- c)  $168 \text{ amu}$
- d)  $142 \text{ amu}$
- e)  $120 \text{ amu}$



37. (3 pts.) The density of a 1.95 M solution of KBr in water is 1.16 g/mL. Find the molality of this solution. The formula weight of KBr is 119.0 amu. Hint: Take a convenient amount of solution such as one liter or one kilogram or one handful. Show work here.

- a) 1.44 mol/kg
- b) 1.86 mol/kg
- c) 1.95 mol/kg
- d) 2.10 mol/kg
- e) 2.31 mol/kg

#### Extra Credit

(2 pts.) Classify each of these solids as ionic, covalent network, metallic, or molecular. Put answers here.

- a)  $\text{CO}_2(\text{s})$
- b)  $\text{C}(\text{diamond})$
- c)  $\text{Mg}(\text{s})$
- d)  $\text{Ba}(\text{NO}_3)_2(\text{s})$