INSTRUCTIONS:
(1) Write your name in the blank titled "NAME" on the scantron form.
(2) Write your section number in the blank titled "SUBJECT" on the scantron form.
(3) Write your Student ID number in the blanks titled "ID NUMBER" on the scantron form. Use "1" in place of the "A" in your ID number.
(4) Fill in BOX C in the "TEST FORM" box on the scantron form.
(5) Perform all your scratch work on this test. You can take it with you at the end of the exam.

You are allowed to use a calculator and one 5x8 index card of notes (both sides).

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Lanthanides

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Actinides

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Some useful constants and relationships:

Specific heat capacities (in J/g K):

- H_2O(J): 4.184; Al(J): 0.900; Cu(J): 0.387; Steel(J): 0.45

101.325 J = 1 L atm

1 atm = 760 Torr

1 J = 1 kg m^2 s^{-2}

1 eV = 1.602 x 10^{-19} J

R = Ideal gas constant: 0.08206 L atm mol^{-1} K^{-1} = 8.31451 J mol^{-1} K^{-1}

Avogadro constant: 6.022 x 10^{23} mole^{-1}

Planck's constant = h = 6.626 x 10^{-34} Js

c = speed of light: 3.00 x 10^8 m/s

R_H = 1.097 x 10^2 nm^{-1}

C_2 = second radiation constant = 1.44 x 10^2 km

\[ T \lambda_{\text{max}} = \frac{1}{5} C_2 \frac{\text{Emitted power (W)}}{\text{Surface area (m}^2\text{)}} = (\text{constant}) T^4 \quad e = mc^2 \quad c = \lambda \nu \]

\[ \frac{1}{\lambda} = R_H \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \quad E = h \nu \quad E = \frac{hc}{\lambda} \quad E(\text{in Joules}) = -2.18 \times 10^{-18} \left( \frac{Z^2}{n^2} \right) \]
1. Given the thermochemical data below, calculate $\Delta H_{\text{rxn}}$ for the reaction

$\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$  \hspace{1cm} $\Delta H_{\text{rxn}} = \, +178.3 \text{ kJ}$

<table>
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<th>Enthalpy, kJ</th>
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<td>$\text{Ca}(\text{s}) + \frac{1}{2} \text{O}_2(\text{g}) \rightarrow \text{CaO}(\text{s})$</td>
<td>$\Delta H_{\text{rxn}} = -635.1$</td>
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<tr>
<td>$\text{Ca}^{2+}(\text{g}) + 2\text{e}^{-} \rightarrow \text{Ca}(\text{g})$</td>
<td>$\Delta H_{\text{rxn}} = -1735$</td>
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<td>$\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$</td>
<td>$\Delta H_{\text{rxn}} = -393.5$</td>
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<tr>
<td>$\text{Ca}(\text{s}) + \frac{1}{2} \text{O}_2(\text{g}) + \text{CO}_2(\text{g}) \rightarrow \text{CaCO}_3(\text{s})$</td>
<td>$\Delta H_{\text{rxn}} = -813.4$</td>
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<tr>
<td>$\text{Ca}(\text{s}) + \text{S}(\text{s}) \rightarrow \text{CaS}(\text{s})$</td>
<td>$\Delta H_{\text{rxn}} = -482$</td>
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a) + 215.2 kJ  
b) – 215.2 kJ  
c) + 178.3 kJ  
d) + 1028.6 kJ  
e) none of the above

**ANSWER:** C. This was quiz 5, problem 3

2. Which of the following is the most plausible structure for the PCl$_4^+$ ion:

a)  \[ \text{[structure a]} \]  
b)  \[ \text{[structure b]} \]  
c)  \[ \text{[structure c]} \]  
d)  \[ \text{[structure d]} \]  
e)  \[ \text{[structure e]} \]  

**ANSWER:** C this problem was straight out of the practice exam

3. What volume of an aqueous solution that is 1.27 M in CH$_3$CO$_2$H is needed to prepare 250.0 mL of a solution that contains 0.160 mol of CH$_3$CO$_2$H?

a) 126 mL  
b) 19.8 mL  
c) 0.64 mL  
d) 2.52 mL  
e) none of the above

**ANSWER:** A
4. 200.0 mL of a 0.5 M solution of \( \text{C}_3\text{H}_9\text{O} \) is diluted to the mark with water in a 500.0 mL volumetric flask. What is the concentration, in molarity, of the final solution?
   a) 0.2 M
   b) 0.05 M
   c) 1.25 M
   d) 100 M
   e) none of the above
   **ANSWER: A**

5. Which of the following compounds has the most covalent bond character?
   a) \( \text{Li}_2\text{O} \)
   b) \( \text{Na}_2\text{O} \)
   c) \( \text{MgO} \)
   d) \( \text{BeO} \)
   e) \( \text{K}_2\text{O} \)
   **ANSWER: D (Be-O has the smallest difference in electronegativity : 3.5-1.5 = 2.0)**

6. Which of the following is a weak acid (check all that apply)?
   a) \( \text{HCl} \)
   b) \( \text{CH}_3\text{COOH} \)
   c) \( \text{HClO}_4 \)
   d) \( \text{HNO}_3 \)
   e) \( \text{HF} \)
   **ANSWER: B and E**

7. A sample contains only C, H, and O. Combustion analysis of 25.00 g of the sample yields 24.99 g of \( \text{H}_2\text{O} \) and 48.83 g of \( \text{CO}_2 \). The empirical formula of the compound is:
   a) \( \text{C}_2\text{H}_4\text{O}_2 \)
   b) \( \text{C}_2\text{H}_6\text{O} \)
   c) \( \text{CH}_3\text{O} \)
   d) \( \text{C}_3\text{H}_2\text{O}_6 \)
   e) \( \text{C}_6\text{H}_{12}\text{O}_6 \)
   **ANSWER: B**
8. What is the oxidation number of bromine in BrO$_3^-$?
   a) -1
   b) +4
   c) +5
   d) +7
   e) none of the above
   **ANSWER: C**

9. What is the balanced net ionic equation for the reaction that occurs when aqueous barium (II) chloride is added to aqueous sodium sulfate?
   a) BaCl$_2$(aq) + Na$_2$S$_2$(aq) → Ba$^{2+}$(aq) + 2Na$^+$(aq) + 2Cl$^-$(aq) + S$_2^-$(aq)
   b) Ba$^{2+}$(aq) + S$_2^-$(aq) → BaS(s)
   c) Ba$^{2+}$(aq) + SO$_3^{2-}$(aq) → BaSO$_3$(s)
   d) Ba$^{2+}$(aq) + SO$_4^{2-}$(aq) → BaSO$_4$(s)
   e) none of the above
   **ANSWER: D**

10. A rocket fuel is composed of two liquids, hydrazine (N$_2$H$_4$) and dinitrogen tetraoxide (N$_2$O$_4$), which ignite on contact to form nitrogen gas and water vapor via the following balanced equation:
    \[ 2\text{N}_2\text{H}_4(l) + \text{N}_2\text{O}_4(l) \rightarrow 3\text{N}_2(g) + 4\text{H}_2\text{O}(g) \]
    If 3.12 mol of N$_2$H$_4$ and 2.17 mol of N$_2$O$_4$ are mixed to form the rocket fuel, how many grams of nitrogen gas are formed?
    a) 131 g
    b) 65.5 g
    c) 91.1 g
    d) 182 g
    e) none of the above
    **ANSWER: A**

11. How many grams of solute are in 185.8 mL of 0.267 M calcium acetate? Assume the density of the solution is 1.00 g/mL.
    \[ \frac{0.267 \text{ mol Ca(C}_2\text{H}_3\text{O}_2)_2}{\text{L}} \times \frac{185.8 \text{ mL}}{1 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{158.167 \text{ g}}{\text{mol Ca(C}_2\text{H}_3\text{O}_2)_2} \]
    a) 185.8 g
    b) 7.85 g
    c) 4.92 g
    d) 0.0496 g
    e) none of the above
    **ANSWER: B. This was a problem from Quiz 2**
12. What is the chemical formula for sodium chlorite?
   a) NaCl
   b) NaClO
   c) NaClO₂
   d) NaClO₃
   e) NaClO₄
   ANSWER: C

13. Which of the following has the largest value of electronegativity?
   a) Be
   b) B
   c) C
   d) N
   e) O
   ANSWER: E

14. The mass percent of Cl⁻ in a seawater sample is determined by titrating 25.00 mL of seawater with AgNO₃ solution, causing a precipitation reaction. An indicator is used to detect the end point (stoichiometric point). If 53.63 mL of 0.2970 M AgNO₃ are required to reach the end point, what is the mass percent of Cl⁻ in the seawater? The density of seawater is 1.024 g/mL.
   a) 24.54 %
   b) 0.06106 %
   c) 0.4884 %
   d) 2.165 %
   e) none of the above
   ANSWER: E. it is 2.21 % Problem from Quiz 3

15. Catalytic methanation is a process used to remove carbon monoxide from hydrocarbon feeds in industrial processes, including the synthesis of ammonia. The skeletal reaction is:

   \[ \text{CO(g)} + 3\text{H}_2(g) \rightarrow \text{CH}_4(g) + \text{H}_2\text{O}(g) \]

   In the balanced equation, how many moles of H₂ are consumed per mole of CO consumed?
   a) 0
   b) 0.67
   c) 3
   d) 1
   e) none of the above
   ANSWER: C
16. Iridium exists in two isotopes, $^{191}\text{Ir}$ (atomic mass 190.9609 amu) and $^{193}\text{Ir}$ (atomic mass 192.9633 amu). If the average atomic mass of Ir is 192.2144 amu, what is the percent abundance of $^{193}\text{Ir}$?
   a) 39.47%
   b) 37.40%
   c) 62.60%
   d) not enough information is given
   e) none of the above
   ANSWER: C 62.60%

17. What is the oxidation state of sulfur in the sulfate ion?
   a) 0
   b) -2
   c) +6
   d) +4
   e) none of the above
   ANSWER: C

18. Which is the correct electron configuration for Fe$^{2+}$ ($\text{g}$):
   a) ![Electron Configuration](image)
   b) ![Electron Configuration](image)
   c) ![Electron Configuration](image)
   d) ![Electron Configuration](image)
   e) none of the above
   ANSWER: C
19. What is the bond order of the S-O bonds in the sulphate ion (SO$_4^{2-}$)?
   a) 0.5
   b) 1
   c) 1.5
   d) 2
   e) none of the above
   ANSWER: C some people put B thinking that “S-O bonds” indicated single bonds. The S-O bonds in sulfate are all equivalent, resonance hybrids with a bond order of 1.5.

20. Give all possible values of the magnetic quantum number ($m_l$) for orbitals that have a value of the angular momentum quantum number ($l$) of 2:
   a) 0
   b) +1, 0
   c) +1, 0 -1
   d) +2, +1, 0, -1, -2
   e) +2, +1, 0
   ANSWER: D

21. The water gas shift reaction is used to produce hydrogen gas industrially:
   \[ \text{CO}(g) + \text{H}_2\text{O}(g) \rightarrow \text{CO}_2(g) + \text{H}_2(g) \quad \Delta H^0 = -41.1 \text{ kJ} \]
   How many kJ of energy are produced when 15.0 g of CO react with 12.0 g of H$_2$O?
   a) 22.0 kJ
   b) 27.4 kJ
   c) 27.3 kJ
   d) 493 kJ
   e) none of the above
   ANSWER: A

22. Which of the following is correctly ranked in order of decreasing size (check all that apply)?
   a) K > Na > Li
   b) Ba > Sr > Ca
   c) O > O$^-$ > O$^{2-}$
   d) F > Cl > Br
   e) Al$^{3+}$ > Al$^{2+}$ > Al
   ANSWER: A and B
23. The empirical formula of a compound that contains 2.45 g of silicon and 12.4 g of chlorine is:
   a) SiCl₅
   b) Si₃Cl
   c) Si₁/₅Cl
   d) not enough information is given
   e) none of the above
   **ANSWER: E it is SiCl₄**

24. Consider the reaction: \[ 2N₂O + Si \rightarrow SiO₂ + 2N₂ \]
   Identify the reducing agent in this reaction.
   a) N₂O
   b) N₂O and Si
   c) SiO₂
   d) N₂ and Si
   e) none of the above
   **ANSWER: E it is Si**

25. Pure water in a small pool (100 L) is heated with 6120 kJ. If the initial temperature of the water is 20.0 °C, what will be the final temperature of the water when it has absorbed all the heat? Assume the pool is perfectly insulating (all the heat goes into the water).
   a) 34.63 °C
   b) 14.63 °C
   c) 20.01 °C
   d) 81.19 °C
   e) none of the above
   **ANSWER: A**

26. What is the molar mass of a compound with the molecular formula C₆H₆N₂?
   a) 108.14 g/mol
   b) 54.07 g/mol
   c) 72.066 g/mol
   d) 86.07 g/mol
   e) none of the above
   **ANSWER: A**
27. The number of grams of Fe in 50.0 g of FeSO₄ is
   a) 50.0 g
   b) 18.4 g
   c) 136 g
   d) 36.8 g
   e) none of the above
   **ANSWER: B**

28. A mass spectrometer was used to measure the mass of an unknown isotope. The ratio of the mass of the unknown isotope to the mass of ¹²C (i.e., the mass ratio) is 2.3314. The relative abundance of the unknown isotope is 92.3%, and the relative abundance of ¹²C is 98.9%. What is the mass of the unknown isotope, in AMU?
   a) 14.020
   b) 12.065
   c) 12.011
   d) 27.977
   e) none of the above
   **ANSWER: D**

29. What is the atomic number of an element that has 14 protons, 15 neutrons, and 10 electrons?
   a) 14
   b) 15
   c) 10
   d) 29
   e) none of the above
   **ANSWER: A**
30. a) Ethylene gas burns in oxygen according to the equation shown below. Using the following table of bond energies, estimate $\Delta H^\circ_{\text{rxn}}$ for the reaction.

\[
\begin{align*}
\text{H} &\quad \text{C} &\quad \text{C} &\quad \text{H} &\quad + &\quad 3 \text{ O} &\quad \equiv &\quad \text{O} &\quad \rightarrow &\quad 2 \text{ O} &\quad \equiv &\quad \text{C} &\quad \equiv &\quad \text{O} &\quad + &\quad 2 \text{ H} &\quad \equiv &\quad \text{O} &\quad \text{H} \\
\end{align*}
\]

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<td>O-O</td>
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<tr>
<td>O=O</td>
<td>498</td>
<td>O-H</td>
<td>467</td>
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a) -232 kJ/mol  
b) +232 kJ/mol  
c) -1304 kJ/mol  
d) not enough information is given  
e) none of the above

**ANSWER:** C -1304 kJ/mol

This was a variant of homework problem 9.57 in the text

\[
\Delta H^\circ_{\text{rxn}} = (\text{all bond energies in reactants}) - (\text{all bond energies in products}) = 4(\text{C-H}) + 1(\text{C≡C}) + 3(\text{O=O}) - 4(\text{C=O}) - 4(\text{O-H}) = 4(413) + 1(614) + 3(498) - 4(799) - 4(467) = -1304 \text{ kJ/mol}
\]

31. What is the empirical formula and the name of the ionic compound formed from Sr and F?

a) SrF, strontium monofluoride  
b) SrF$_2$, strontium difluoride  
c) SrF, Ferrite  
d) SrF$_3$, stannic fluoride  
e) SrF$_2$, stannous fluoride

**ANSWER:** B
32. Which molecules are **not** polar (check all that apply)?
   a) CO₂
   b) BF₃
   c) CH₄
   d) ICl₃
   e) PCl₅
   
   **ANSWER:** A, B, C, and E

33. Which of the following compounds are paramagnetic (check all that apply)?
   a) NO₂
   b) Ag₉(g)
   c) NO₃⁻
   d) N₂
   e) CF₂Cl₂
   
   **ANSWER:** A and B are paramagnetic

34. How many molecules of sucrose (C₁₂H₂₂O₁₁) are contained in 1.00 microliters of a solution 1.00 picomolar in sucrose?
   a) 342
   b) 602,000
   c) 1 x 10⁻¹²
   d) 1 x 10⁻⁶
   e) none of the above
   
   **ANSWER:** B

35. If the thermal decomposition of 38.2 g of CaCO₃ generates 12.7 g of CO₂ by the following reaction:
   \[
   \text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2
   \]
   what is the percent yield of the reaction?
   a) 75.6 %
   b) 16.8 %
   c) 33.2 %
   d) 28.9 %
   e) none of the above
   
   **ANSWER:** A
36. What is the electron configuration of the (gas phase) Zn$^{2+}$ ion?
   a) [Ar] 4s$^2$ 3d$^{10}$
   b) [Ar] 4s$^2$ 3d$^5$
   c) [Ar] 4s$^2$ 3d$^8$
   d) [Ar] 3d$^{10}$
   e) none of the above
   ANSWER: D

37. Which of the following Lewis structures of NO$_2$ is the most correct?

   ![Lewis structures]

   a) O=N=O
   b) O=N=O
   c) O=N=O
   d) O=N=O
   e) O=N=O

   ANSWER: A (D is incorrect because nitrogen exceeds an octet of electrons)

38. Using VSEPR theory, what is the molecular shape of IBr$_3$?
   a) tetrahedral
   b) trigonal planar
   c) trigonal pyramidal
   d) t-shaped
   e) seesaw
   ANSWER: D

39. The wavelength of red light is 630 nm. Which of the following bonds can be broken by a single photon of this energy (approximate bond energies are given next to each bond)? Check all that apply.
   a) I-I (151 kJ/mol)
   b) C-O (358 kJ/mol)
   c) C=O (745 kJ/mol)
   d) N≡N (945 kJ/mol)
   e) none of the above
   ANSWER: A (the energy works out to 190 kJ/mol)
40. In the following reaction: 
   \[ 2\text{KClO}_3 + 3\text{C} \rightarrow 3\text{CO}_2 + 2\text{KCl} \]

   Which compound is the reducing agent?
   a) \( \text{KClO}_3 \)
   b) \( \text{C} \)
   c) \( \text{KClO}_3 \) and \( \text{C} \)
   d) \( \text{CO}_2 \)
   e) \( \text{KCl} \)

   **ANSWER:** B

41. Consider the reaction of nitrogen dioxide with water (not balanced):
   
   \[ 3\text{NO}_2(g) + 1\text{H}_2\text{O}(l) \rightarrow 2\text{HNO}_3(aq) + 1\text{NO}(g) \]

   In the balanced reaction, if 5.00 moles of \( \text{NO}_2 \) are consumed in this reaction, how many moles of \( \text{HNO}_3 \) are produced?
   a) 5.00
   b) 7.50
   c) 2.50
   d) 3.33
   e) none of the above

   **ANSWER:** D

42. Titanium has a density of 4.51 g/mL. If a piece of Ti is dropped into a graduated cylinder containing 10.567 mL of water and the water level rises to 11.077 mL, what is the mass of the Ti sample?
   a) 4.51 g
   b) 2.30 g
   c) 0.51 g
   d) 1.25 g
   e) none of the above

   **ANSWER:** B

43. The transition of an electron from the principle quantum number \( n = 2 \) to \( n = 6 \) in atomic hydrogen is caused by absorption of a photon of what wavelength?
   a) 274 nm
   b) 410 nm
   c) 365 nm
   d) 486 nm
   e) none of the above

   **ANSWER:** B
44. Combustion analysis of a 4.00 g sample of C$_9$H$_8$O$_4$ produces how many grams of water?
   a) 8.79  
   b) 4.00  
   c) 2.00  
   d) 1.60  
   e) none of the above  
   ANSWER: D

45. How many unpaired electrons are there in a ground state atom of Fe$_{(g)}$?
   a) 0  
   b) 8  
   c) 4  
   d) 5  
   e) none of the above  
   ANSWER: C

46. The set of quantum numbers $n = 3$, $l = 2$, $m_l = 0$ and $m_s = +1/2$ describes an electron in which orbital?
   a) 2f  
   b) 5s  
   c) 3d  
   d) 3p  
   e) none of the above  
   ANSWER: C

47. Which reaction represents the 2nd ionization energy of Si?
   a) Si$^-_{(g)}$ + e$^-$ $\rightarrow$ Si$^{2-}_{(g)}$  
   b) Si$^{+}_{(g)}$ $\rightarrow$ Si$^{2+}_{(g)}$ + 2e$^-$  
   c) Si$^+_{(g)}$ $\rightarrow$ Si$^{3+}_{(g)}$ + e$^-$  
   d) Si$^{+}_{(g)}$ + e$^-$ $\rightarrow$ Si$^-_{(g)}$  
   e) Si$^{+}_{(g)}$ + 2e$^-$ $\rightarrow$ Si$^{2-}_{(g)}$  
   ANSWER: C

48. What is the value of the F-B-F bond angle ($\theta$) in BF$_3$?
   a) $120^\circ$ $< \theta < 180^\circ$  
   b) $109.5^\circ$ $< \theta < 120^\circ$  
   c) $90^\circ$ $< \theta < 109.5^\circ$  
   d) $60^\circ$ $< \theta < 90^\circ$  
   e) $\theta = 120^\circ$  
   ANSWER: E
49. Which of the following ions has the smallest radius?
   a) K⁺
   b) Ca²⁺
   c) As³⁻
   d) Se²⁻
   e) Br⁻

   ANSWER: B

50. What is the percent by mass of carbon in a compound with the molecular formula C₃H₄N?
   a) 66.6%
   b) 3.75%
   c) 37.5%
   d) 72.1%
   e) none of the above

   ANSWER: A

51. Which of the following songs best describes your experience with Chem 6A?
   a) “Viva La Vida” – Coldplay
   b) “Bad Day” – Alvin and the Chipmunks remake
   c) “Feels Like Home” – Edwina Hayes
   d) “Ring of Fire” – Johnny Cash
   e) none of the above (write-in on back of scantron form)