ACS Scholarship Exam
North Central College
May 24, 2008

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question. You have 75 minutes.

INFORMATION THAT MAY BE OF USE TO YOU IN THE EXAM

$N_A = 6.022 \times 10^{23}$/mol R = 8.31447J/(mol·K) or 0.08206 L atm/(mol K)

Density of nucleus ≈ 10^{14} g/mL

Periodic Table

IA												IIIA	IVA	VA	VIA	VIIA	0
1 H 1.008	IIA																2 He 4.003
3 Li 6.941	4 Be 9.012											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 24.31	IIIB	IVB	VB	VIB	VIIB		VIIIB		IB	IIB	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 58.70	29 Cu 63.55	30 Zn 65.38	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 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 * La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226.0)	89 ** Ac (227)	104 Rf	105 Ha	106 Unh	107 Uns	108	109 Une									

* 58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
** 90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (244)	94 Pu (242)	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 (260)

1) The density of mercury is 13.55 g/ cm^3. What mass of mercury is required to fill a 2.0 ounce bottle? An ounce is 29.57 cm^3.

A) 2.2 g

B) 400 g

C) 0.0025 g

D) 0.5 g

E) 800 g

2) What is the formula of ammonium nitrate?

A) $(NH_4)_2NO_3$

B) NH_4NO_3

C) NH_4N

D) $NH_4(N0_3)_2$

E) $(NH_4)_3N$

3) How many iron atoms are in the formula for iron(lII) oxide?

A) 6

B) 4

C) 3

D) 2

E) 1

4) Ammonia can be prepared by the reaction of magnesium nitride with water. The products are ammonia and magnesium hydroxide. When the equation is written and balanced, the coefficient of magnesium hydroxide is

A) 8

B) 6

C) 1

D) 2

E) 3

5) Avogadro's number is big. If you had 6.02×10^{23} dollars, and could spend it at 1 billion (10^9) dollars per second for your entire life (~ 75 years), what approximate percentage of your original money would you have left?

A) 50%

B) 0%

C) ~ 100%

D) 10%

E) 75%

6) If it were possible to obtain a cubic centimeter of pure atomic nuclei, its mass would be approximately

A) 1.2×10^{11} kg.

B) 1 kg.

C) 19 g.

D) 1 g.

E) 100 g

7) How many molecules are in 237 g (about a cup) of water?

A) 4267

B) 6.02×10^{23}

C) 13.1

D) 7.93×10^{24}

E) 237

8) Acetylene (C_2H_2) burns in pure oxygen with a very hot flame. Assuming complete combustion, how much oxygen is required to react with 52.0 g of acetylene?

A) 52.0 g

B) 90.0 g

C) 32.0 g

D) 160.0 g

E) 64.0 g

9) The number of moles of NaOH that are in 250 mL of a 3 molar solution is

A) 1.0 moles.

B) 0.75 moles.

C) 0.25 moles.

D) 1.5 moles.

E) 4.0 moles.

10) The observation that 20 g of hydrogen gas always combines with 160 g of oxygen gas to form 180 g of water, even when there is more than 160 g of oxygen present in the reaction container, illustrates the law of

A) conservation of mass.

B) ideal gases.

C) multiple proportions.

D) definite proportions.

E) thermodynamics.

11) Nitrogen forms a number of different compounds with oxygen, depending upon the experimental conditions. This type of observation concerning the behavior of matter is summarized by

A) thermodynamics.

B) the law of multiple proportions.

C) the law of conservation of mass.

D) the law of definite proportions.

E) the law of constant composition.

12) For ICl_2^-, the oxidation state of I, formal charge of I, hybridization of I and shape of the anion are

A) -1, 1, *sp*, and linear.

B) 1, -1, sp^3d, and linear.

C) 3, -1, sp^2, and bent.

D) 5, -2, sp^3d, and bipyramidal.

E) 1, 1, sp^2, and bent.

13) The following reaction occurs in acidic solution:

$Cr_2O_7^{2-} + Fe^{2+} \rightarrow Cr^{3+} + Fe^{3+}$

The coefficients of $Cr_2O_7^{2-}$, Fe^{2+}, Cr^{3+},and Fe^{3+}in the final balanced equation are

A) 1, 3, 1, 3

B) 1, 5, 1, 5

C) 1, 1, 2, 1

D) 1, 10, 2, 10

E) 1, 6, 2, 6

14) Sodium bisulfite converts bromine (Br_2) to bromide (Br^-). Sodium bisulfite is

A) a base.

B) an acid.

C) an oxidizing agent.

D) a reducing agent.

E) pyrophoric

15) The density of O_2 gas at 1 atmosphere of pressure and 0˚C is

A) 0.714 g/L

B) 1.69 g/L

C) 1.56 g/L

D) 1.00 g/L.

E) 1.43 g/L

16) Use the ideal gas law to calculate the volume occupied by 0.200 mol of nitrogen gas at 1.00 atm pressure and at 27˚C.

A) 22.4 L

B) 4.92 L

C) 0.0821L

D) 0.441 L

E) 0.203 L

17) NO and NO_2 are known to exist and play a key role in the formation of photochemical smog. The free energies of formation for NO and NO_2 are +20.7 kcal/mol and +12.4 kcal/mol, respectively. NO and NO_2 are thermodynamically

A) stable with respect to N_2 and O_2 because each atom in NO and NO_2 has a noble gas configuration.

B) stable with respect to N_2 and O_2 because each atom in NO and NO_2 are paramagnetic compounds.

C) stable with respect to N_2 and O_2 because the free energies of formation are 0.0 kcal/mol for N_2 and O_2.

D) unstable with respect to N_2 and O_2 but exist because they are slow to decompose to N_2 and O_2.

E) unstable with respect to N_2 and O_2 due to reasons given in 1 and 3 above.

18) What is the electronic configuration of nickel in $Ni(NH_3)_2Cl_2$?

A) $[Ar]4s^2 3d^8$

B) $[Ar]4s^2 3d^6$

C) $[Ar]4s^0 3d^{10}$

D) $[Ar]4s^1 3d^7$

E) $[Ar]4s^0 3d^8$

19) Mendeleev organized the elements

A) by increasing atomic weight and similar properties.

B) alphabetically by name.

C) by number of electrons.

D) by increasing atomic number and similar properties.

E) by electronic configuration

20) Which has the lowest ionization energy (potential): C, Si, or P? Which is smaller (in size): F or F^{-1}?

A) C, F

B) Si, F

C) P, F

D) P, F^{-1}

E) Si, F^{-1}

21) According to the Pauli Exclusion Principle, two electrons in the same shell cannot have the same

A) l

B) m_l and m_s

C) l, m_l or m_s

D) l, m_l and m_s

E) m_l or m_s

22) Which is a result of the mathematically based quantum view of electrons in atoms?

A) The position of every electron in an atom is precisely known.

B) The position of electrons in atoms is not important.

C) The position and speed (momentum) of all electrons can be precisely determined.

D) All electrons have the same position in atoms.

E) The most probable position of each electron can be predicted.

23) Which set contains only molecular oxides?

A) Na_2O, MgO, Al_2O_3

B) CaO, Ga_2O_3, SiO_2

C) Ga_2O_3, SiO_2, P_4O_{10}

D) SiO_2, P_4O_{10}, SO_2

E) P_4O_{10}, SO_2, ClO_2

24) Which molecule has a net dipole moment?

A) $SiCl_4$

B) BF_3

C) NF_3

D) *trans*-$Pt(NH_3)_2Cl_2$

E) $TiCl_4$

25) Which set is arranged in order of increasing size?

A) $Na^+ < Mg^{2+} < K^+ < Ca^{2+}$

B) $Mg^{2+} < Na^+ < F^- < O^{2-}$

C) $O^{2-} < F^- < Na^+ < Mg^{2+}$

D) $Se^{2-} < Br^- < S^{2-} < Cl^-$

E) $Cl^- < Br^- < S^{2-} < Se^{2-}$

26) Which is the correct order of increasing electronegativity (left to right)?

A) Cl < H < B < Al < Mg

B) Mg < B < Al < H < Cl

C) H < Mg < Al < B < Cl

D) Mg < Al < B < H < Cl

E) None of the above

27) The primary reason $NaCl_2$ is not stable is

A) the $NaCl_2$ lattice energy is too large.

B) the sum of the first and second ionization energies of Na is too large.

C) the Na^{2+} ion is too small to form a crystal lattice.

D) addition of an electron to Cl is not exothermic.

E) addition of an electron to Na is not exothermic.

28) The following enthalpies are known:

	ΔH(kcal)
$Rb(s) \rightarrow Rb(g)$	19.9
$Rb(g) \rightarrow Rb^+(g) + e^-$	95.9
$Cl_2(g) \rightarrow 2\ Cl(g)$	57.8
$Cl(g) + e^- \rightarrow Cl^-(g)$	-90.7
$Rb(s) + \frac{1}{2}\ Cl_2(g) \rightarrow RbCl(s)$	-104.9

The lattice energy of rubidium chloride, that is,

$Rb^+(g) + Cl^-(g) \rightarrow RbCl(s)$ is

A) -159.4 kcal/mol

B) -187.8 kcal/mol

C) 300.5 kcal/mol

D) -158.9 kcal/mol

E) -22.0 kcal/mol

29) The compound with the greatest degree of covalency is:

A) BeS

B) NaF

C) LiCl

D) MgO

E) None of the above since all are completely ionic.

30) Consider the molecules CO_2 and N_2O. The structures of the most stable isomers of these compounds are

A) OCO and NON

B) COO and NON

C) OCO and NNO

D) COO and NNO

E) OOC and ONN

31) Which is **not** linear?

A) CS_2

B) XeF_2

C) I_3^{-1}

D) NO_2^{+1}

E) NO_2^{-1}

32) If a molecule of the type MX_3, where M is a second period (Na-Ar) element, has a dipole moment of zero, then the sigma bonding orbitals employed by M are

A) sp^2 hybrid orbitals

B) sp^3 hybrid orbitals

C) *sp* hybrid orbitals

D) sp^3d hybrid orbitals

E) unhybridized *p* orbitals

33) In which one of the following molecules is hydrogen bonding **NOT** a factor?

A) HBr

B) NH_3

C) H_2O

D) CH_3OH

E) HF

34) The reaction

$2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$

is a slow but important process in the conversion of S to H_2SO_4. The reaction proceeds much faster via the sequence

Step 1 $2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$

Step 2 $2\ NO_2(g) + 2\ SO_2(g) \rightarrow 2\ NO(g) + 2\ SO_3(g)$

Net $2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$

According to this sequence

A) NO and NO_2 are catalysts

B) NO is a catalyst, and NO_2 is an intermediate.

C) NO is an intermediate, and NO_2 is a catalyst.

D) NO and NO_2 are intermediates.

E) None of these statements are correct.

35) In the equilibrium

$HS^-(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + S^{2-}(aq)$

the change in which of the following would effectively increase the S^{2-} concentration?

A) addition of H_3O^+

B) increased pressure

C) addition of Ag^+

D) addition of OH^-

E) addition of H_2SO_4

36) All of the following are strong acids except

A) phosphoric acid.

B) hydrochloric acid.

C) nitric acid.

D) sulfuric acid.

E) hydroiodic acid

37) The pH of rain collected on a remote island in the Pacific is assumed to be unaffected by human pollution. The pH of the rainwater is

A) between 7 and 14.

B) equal to 7.

C) between 1 and 7.

D) equal to 0.

E) between 0 and 1

38) Which is the strongest base?

A) $Mg(OH)_2$

B) $Ca(OH)_2$

C) $Al(OH)_3$

D) $Si(OH)_4$

E) NH_3

39) The conjugate base of HPO_4^{2-} is

A) H_3PO_4

B) $H_2PO_4^{-1}$

C) PO_4^{3-}

D) OH^{-1}

E) Na_2HPO_4

40) For $Mn^{2+} \rightarrow Mn^{3+} + e^-$ $E^\circ = -1.51$ V

A) Mn^{2+} is a good oxidizing agent

B) Mn^{2+} is a good reducing agent

C) Mn^{3+} is a good oxidizing agent

D) Mn^{3+} is a good reducing agent

E) It depends on if the reaction of interest is under $[H^+] = 1$ M conditions.

41) Which element is an alkaline earth?

A) Cl

B) Ar

C) Ca

D) K

E) Ce

42) With respect to volume, approximately what percentage of the air we breathe is composed of elemental oxygen, O_2?

A) = 20%

B) = 80%

C) = 10%

D) = 50%

E) = 100%

43) Aluminum is more reactive than iron, yet it is used today for a variety of applications in which iron would corrode (cans, rain gutters, etc). The reason for the corrosion durability of aluminum is that

A) it is galvanized.

B) aluminum does not react with oxygen.

C) all aluminum products are treated with a plastic coating.

D) aluminum does not undergo oxidation.

E) very unreactive aluminum oxide forms a thin layer on aluminum.

44) The black tarnish on silver is

A) Ag_2S.

B) AgCl.

C) AgOH.

D) Ag_2O.

E) $AgNO_3$

45) The existence of many different types of organic compounds is a result of the

A) capacity of carbon to form ionic bonds.

B) high electronegativity of hydrogen.

C) ability of carbon to bond with itself.

D) formation of pi bonds between carbon and hydrogen atoms.

E) the high ionization energy of carbon.

46) How many different structural isomers are there for a hydrocarbon with the formula C_5H_{12}?

A) 0

B) 1

C) 2

D) 3

E) 4

47) A hydrocarbon with six carbon atoms containing one ring and a double bond will have the formula

A) C_6H_{16}.

B) C_6H_{14}.

C) C_6H_{13}.

D) C_6H_{12}.

E) C_6H_{10}.

48) The general formula for a ketone is

A) RCOOH.

B) RCOOR'.

C) RCOR'.

D) ROR'.

E) RCHO

49) The atomic number increases by 1 during what type of radioactive decay?

A) beta

B) gamma

C) alpha

D) delta

E) none of these

50) Exposure to radioactive material is considered safe after 10 half-lives because

A) less than a tenth of 1% of the material remains.

B) all of the material will have decayed at that time.

C) ten is an even number.

D) less than 12.5% of the material remains.

E) The material has stopped giving off harmful radiation by then.