1. The enthalpy change for the following reaction is 759 kJ. Calculate the average Cl-F bond energy.

$$ClF_3(g) \rightarrow Cl(g) + 3 F(g)$$

A. 88.0
B. 253
C. 312
D. 514
E. 1540

2. The bond angles in XeF_4 are _____ .

A. exactly 90°
B. slightly less than 90°
C. exactly 109.5°
D. slightly less than 109.5°
E. exactly 120°

3. Write resonance structures for CO_3^{2-} . Based on these structures one can conclude that the bond order of the C - O bond is

A. ½
B. ⅔
C. 1
D. 1 ⅓
E. 1 ⅔

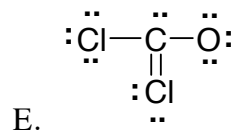4. In the following oxidation reaction the shape of the reactant is ___and the shape of the product is ___ .
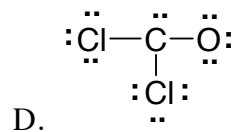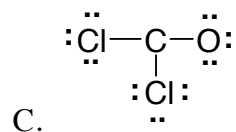
$$PCl_4^- \rightarrow PCl_4^+ + 2 e^-$$

A. see-saw, tetrahedral
B. tetrahedral, see-saw
C. T-shaped, tetrahedral
D. T-shaped, square planar
E. square planar, T-shaped

5. Draw the Lewis formula for BrF₃. What term describes the shape of this species?

    A. planar trigonal
    B. trigonal pyramid
    C. T shaped
    D. square planar
    E. tetragonal pyramid

6. Which of the following is the correct Lewis structure for COCl₂?

A.
$$:\ddot{C}l-\underset{\underset{\displaystyle:\ddot{C}l:}{|}}{C}=\ddot{O}:$$

B.
$$:\ddot{C}l=\underset{\underset{\displaystyle:\ddot{C}l:}{|}}{C}-\ddot{O}:$$

C.
$$:\ddot{C}l-\underset{\underset{\displaystyle:\ddot{C}l:}{|}}{C}-\ddot{O}:$$

D.
$$:\ddot{C}l-\underset{\underset{\displaystyle:\ddot{C}l:}{|}}{C}-\ddot{O}:$$

E.
$$:\ddot{C}l-\underset{\underset{\displaystyle:\ddot{C}l}{||}}{C}-\ddot{O}:$$
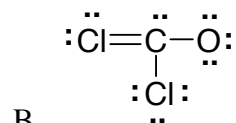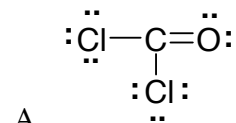
7. Which of the following is the correct Lewis structure for NO_2^- ?

A. :O=N=O:

B. :O=N=O:

C. :O−N−O:

D. :O−N−O:

E. :O−N=O:
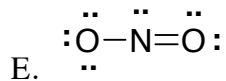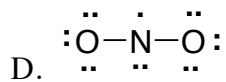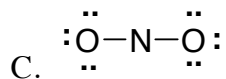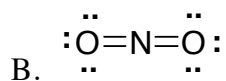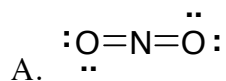
8. Which of the following is a nonpolar molecule?

A. PCl_5
B. ClF_3
C. BrF_5
D. BrF
E. $CHCl_3$

9. Which of the following has bond angles of approximately 90°?

1) ClF_3 2) BF_3 3) ClO_3^- 4) SF_4 5) $GeCl_4$

A. 1 and 4
B. 2 and 3
C. 3 only
D. 4 only
E. 5 only

10. Which of the species in the following list is trigonal planar?

1) ClF_3 2) BF_3 3) ClO_3^- 4) $GeCl_3^+$ 5) SiH_3^-

A. 1 only
B. 3 only
C. 1 and 3
D. 2 and 4
E. 3 and 5

11. A 352.2 mL sample of O_2 is collected at 738 mm Hg. What would be the volume (mL) at 1.00 atm assuming that the temperature remains constant?

   A. 331
   B. 342
   C. 350
   D. 339
   E. 328

12. Calculate the density, g/L, of Freon-12, CF_2Cl_2 at STP.

   A. 3.80
   B. 5.40
   C. 4.35
   D. 6.14
   E. 4.98

13. Four identical 1.0-L flasks contain the following gases each at 0°C and 1 atm pressure. For which gas do the molecules have the smallest average kinetic energy?

   A. HCl
   B. Cl_2
   C. CH_4
   D. NH_3
   E. all are the same

14. A 2.00 L sample of air at -50.0°C has a pressure of 700. torr. What will be the new pressure (torr) if the temperature is raised to 50.0°C and the volume is increased to 4.00 L?

   A. 411
   B. 443
   C. 485
   D. 506
   E. 552

15. The density of a hydrocarbon at STP is 1.97 g/L. What is the molecular weight of the gas?

    A. 16.3
    B. 30.6
    C. 44.1
    D. 26.2
    E. 40.7

16. A 0.815 g sample of a mixture contains copper and aluminum. Aluminum reacts with HCl but copper does not. What is the % Al if 927 mL of hydrogen gas is collected by displacement of water at 740. mm Hg and 20.0°C. The vapor pressure of water is 17.5 mm Hg.

$$2 \text{ Al(s)} + 6 \text{ HCl(aq)} \longrightarrow 2 \text{ AlCl}_3\text{(aq)} + 3 \text{ H}_2$$
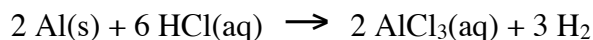
    A. 81.7
    B. 80.8
    C. 79.2
    D. 85.3
    E. 77.1

17. Calculate the mass (g) of magnesium required to produce 325 mL of hydrogen gas at 0.00°C and 1.00 atm.

$$\text{Mg(s)} + 2 \text{ HCl(aq)} \longrightarrow \text{MgCl}_2\text{(aq)} + \text{H}_2\text{(g)}$$
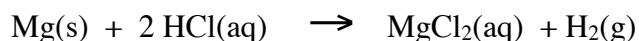
    A. 0.353
    B. 0.391
    C. 0.323
    D. 0.421
    E. 0.290

18. A 0.995 g gaseous sample of $C_2H_3X_3$ has a volume of 355 mL at 769 mm Hg at 95°C. What is the atomic weight of X?

    A. 19.0
    B. 34.4
    C. 16.0
    D. 32.0
    E. 79.9

19. A mixture of 0.50 mole N_2 and 0.50 mole of CO_2 is introduced into a 10.0 L container at 25°C. The container has pinhole leak. After a period of time:

   A. the partial pressure of N_2 exceeds that of CO_2 in the remaining gas
   B. the partial pressure of CO_2 exceeds that of N_2 in the remaining gas
   C. the partial pressures of the two gases remain equal throughout this time

20. A mixture of hydrogen and helium is 25.0% hydrogen by mass. What is the partial pressure (mm Hg) of helium in the mixture at STP?

   A. 457
   B. 303
   C. 520
   D. 250
   E. 280

21. Which of the following can form intermolecular hydrogen bonds in the pure liquid?

```
      H  H  H  H              H  H      H            H      H
      |  |  |  |              |  |      |            |      |
   H—C—C—C—N—H           H—C—C—N—C—H         H—C—N—C—H
      |  |  |               |  |  |  |            |      |
      H  H  H              H  H  H  H           H   CH₃ H
 1)                     2)                    3)
```
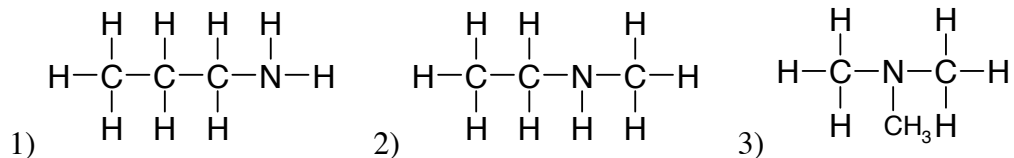
   A. 1 only
   B. 2 only
   C. 3 only
   D. 1 and 2
   E. 2 and 3

22. Given the following boiling point data, which one of the liquids would you expect to have the highest vapor pressure at room temperature (normal boiling point is parenthesis)?

   A. Water, H_2O (100°C)
   B. methanol, CH_3OH (64.96°C)
   C. ethanol, CH_3CH_2OH (78.5°C)
   D. diethyl ether, CH_3CH_2-O-CH_2CH_3 (34.5°C)
   E. ethylene glycol, HO-CH_2-CH_2-OH (198°C)

23. Which molecule or ion below has the shortest oxygen-oxygen bond length?

   a. O_2
   b. O_2^{2-}
   c. H_2O_2 (i.e HOOH)
   d. All of the above have equal oxygen-oxygen bond lengths

24. In which of the molecules below does oxygen have the greatest partial negative charge?

   a. CO_2
   b. O_2
   c. H_2O
   d. NO
   e. CO

25. Which molecule in each pair has the longest bond length?
	I. O_2 or F_2	**II. NH_3 or PH_3**	**III. NO^+ or NO^-**
a.	I. O_2	II. NH_3	III. NO^+
b.	I. O_2	II. PH_3	III. NO^-
c.	I. F_2	II. NH_3	III. NO^+
d.	I. F_2	II. PH_3	III. NO^-
e.	I. O_2	II. PH_3	III. NO^+

26. What is the bond order of He_2^+? (Hint: Consider its molecular orbital diagram).

   a. -1
   b. $-1/2$
   c. 0
   d. $+1/2$
   e. $+1$

27. Which statement is true about sulfur dioxide?

   a. SO_2 is a non-polar compound
   b. Sulfur dioxide has two equivalent sulfur-oxygen bonds of 3/2 bond order
   c. Experimentally, one oxygen atom bears a charge of -1 and the other of zero
   d. According to hybrid theory, the central sulfur atom is sp hybridized
   e. None of the above statements are true

28. Which molecule below contains the weakest carbon-oxygen bond?
   a. CO
   b. CO_2
   c. CH_3OH
   d. CH_2O
   e. H_2CO_3

Use the diagram below for the next 4 questions:

B$_2$, C$_2$, N$_2$, and their ions: **O$_2$, F$_2$, Ne$_2$, and their ions:**
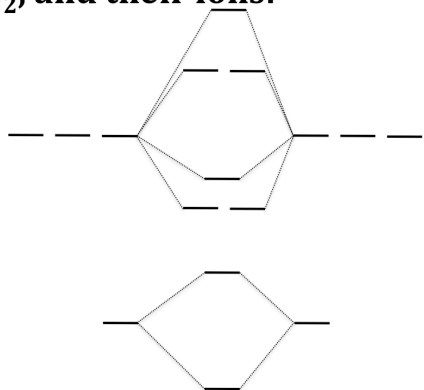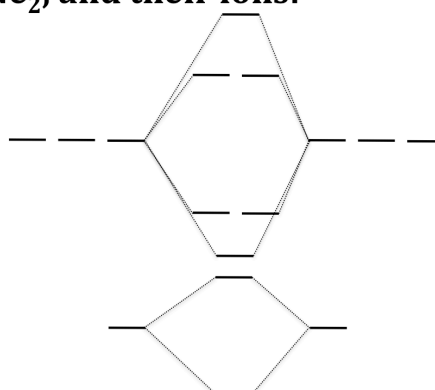
29. Which molecule below has the lowest bond order?
    a. C_2^{2+}
    b. C_2
    c. C_2^{2-}
    d. O_2
    e. O_2^-

30. Which statement is true for the molecules/ions in the answers to question #29?

    a. All the molecules/ions are paramagnetic
    b. All the molecules/ions are paramagnetic except one
    c. All the molecules/ions are paramagnetic except two
    d. All the molecules/ions are diamagnetic except two
    e. All the molecules/ions are diamagnetic except one

31. An important property of molecules is the energy difference between the highest energy molecular orbital occupied with electrons (HOMO) and the lowest energy molecular orbital unoccupied with electrons (LUMO). Identify the HOMO of N$_2$.

    a. σ^*_{2s}
    b. σ_{2p}
    c. π_{2p}
    d. π^*_{2p}
    e. σ^*_{2p}

32. Which ranking of F$_2$, N$_2$, and B$_2$ by order of increasing bond length is correct?

    a. $F_2 < N_2 < B_2$
    b. $B_2 < N_2 < F_2$
    c. $N_2 < F_2 < B_2$
    d. $N_2 < B_2 < F_2$
    e. $B_2 < F_2 < N_2$

Fundamental Constants*

Atomic mass unit	1 amu	$= 1.660538782 \times 10^{-27}$ kg
	1 g	$= 6.02214179 \times 10^{23}$ amu
Avogadro's number	N	$= 6.02214179 \times 10^{23}$/mol
Boltzmann's constant	k	$= 1.3806504 \times 10^{-23}$ J/K
Electron charge	e	$= 1.602176487 \times 10^{-19}$ C
Faraday's constant	F	$= 9.64853399 \times 10^{4}$ C/mol
Gas constant	R	$= 0.082058205$ L-atm/mol-K
		$= 8.314472$ J/mol-K
Mass of electron	m_e	$= 5.48579909 \times 10^{-4}$ amu
		$= 9.10938215 \times 10^{-31}$ kg
Mass of neutron	m_n	$= 1.008664916$ amu
		$= 1.674927211 \times 10^{-27}$ kg
Mass of proton	m_p	$= 1.007276467$ amu
		$= 1.672621637 \times 10^{-27}$ kg
Pi	π	$= 3.1415927$
Planck's constant	h	$= 6.62606896 \times 10^{-34}$ J-s
Speed of light	c	$= 2.99792458 \times 10^{8}$ m/s

Provided equations

$\Delta H = q_{rxn}$, $\quad q_{rxn} = -q_{surr}$, $\quad q = mC_s\Delta T$

$c = \lambda\nu$, $\quad E = h\nu$, $\quad \lambda = h/mv$, $\quad \Delta x \cdot m\Delta v \geq h/4\pi$,

$E_n(H) = -2.179 \times 10^{-18}$ J $(1/n^2)$, $\quad \mu = Q \cdot d$,

$E_{el} = \kappa Q_1 Q_2/d$, $\quad 1$ D $= 3.34 \times 10^{-30}$ C-m

$PV = nRT$, $\quad v_{rms} = \sqrt{\dfrac{3RT}{M}}$, $\dfrac{rate_A}{rate_B} = \sqrt{\dfrac{M_B}{M_A}}$

$\left(P + \dfrac{n^2 a}{V^2}\right)(V - nb) = nRT$,

Useful Conversion Factors and Relationships

Length
SI unit: meter (m)

1 km	= 0.62137 mi
1 mi	= 5280 ft
	= 1.6093 km
1 m	= 1.0936 yd
1 in.	= 2.54 cm (exactly)
1 cm	= 0.39370 in.
1 Å	$= 10^{-10}$ m

Mass
SI unit: kilogram (kg)

1 kg	= 2.2046 lb
1 lb	= 453.59 g
	= 16 oz
1 amu	$= 1.660538782 \times 10^{-24}$ g

Temperature
SI unit: Kelvin (K)

0 K	$= -273.15$ °C
	$= -459.67$ °F
K	= °C + 273.15
°C	$= \frac{5}{9}$ (°F − 32°)
°F	$= \frac{9}{5}$ °C + 32°

Energy (derived)
SI unit: Joule (J)

1 J	$= 1$ kg-m^2/s^2
1 J	= 0.2390 cal
	$= 1$ C $\times$ 1 V
1 cal	= 4.184 J
1 eV	$= 1.602 \times 10^{-19}$ J

Pressure (derived)
SI unit: Pascal (Pa)

1 Pa	$= 1$ N/m^2
	$= 1$ kg/m-s^2
1 atm	= 101,325 Pa
	= 760 torr
	= 14.70 lb/in^2
1 bar	$= 10^5$ Pa
1 torr	= 1 mm Hg

Volume (derived)
SI unit: cubic meter (m³)

1 L	$= 10^{-3}$ m^3
	$= 1$ dm^3
	$= 10^3$ cm^3
	= 1.0567 qt
1 gal	= 4 qt
	= 3.7854 L
1 cm^3	= 1 mL
1 in^3	= 16.387064 cm^3

Periodic Table

1A																	8A
1 **H** 1.00794	2A											3A	4A	5A	6A	7A	2 **He** 4.002602
3 **Li** 6.941	4 **Be** 9.012182											5 **B** 10.811	6 **C** 12.0107	7 **N** 14.0067	8 **O** 15.9994	9 **F** 18.9984032	10 **Ne** 20.1797
11 **Na** 22.989769	12 **Mg** 24.3050	3B	4B	5B	6B	7B	8B		1B	2B		13 **Al** 26.9815386	14 **Si** 28.0855	15 **P** 30.973762	16 **S** 32.065	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.0983	20 **Ca** 40.078	21 **Sc** 44.955912	22 **Ti** 47.867	23 **V** 50.9415	24 **Cr** 51.9961	25 **Mn** 54.938045	26 **Fe** 55.845	27 **Co** 58.933195	28 **Ni** 58.6934	29 **Cu** 63.546	30 **Zn** 65.38	31 **Ga** 69.723	32 **Ge** 72.64	33 **As** 74.92160	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.798
37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.90585	40 **Zr** 91.224	41 **Nb** 92.90638	42 **Mo** 95.96	43 **Tc** [98]	44 **Ru** 101.07	45 **Rh** 102.90550	46 **Pd** 106.42	47 **Ag** 107.8682	48 **Cd** 112.411	49 **In** 114.818	50 **Sn** 118.710	51 **Sb** 121.760	52 **Te** 127.60	53 **I** 126.90447	54 **Xe** 131.293
55 **Cs** 132.9054519	56 **Ba** 137.327	57-71 Lanthanides	72 **Hf** 178.49	73 **Ta** 180.94788	74 **W** 183.84	75 **Re** 186.207	76 **Os** 190.23	77 **Ir** 192.217	78 **Pt** 195.084	79 **Au** 196.966569	80 **Hg** 200.59	81 **Tl** 204.3833	82 **Pb** 207.2	83 **Bi** 208.98040	84 **Po** [209]	85 **At** [210]	86 **Rn** [222]
87 **Fr** [223]	88 **Ra** [226]	89-103 Actinides	104 **Rf** [267]	105 **Db** [268]	106 **Sg** [271]	107 **Bh** [272]	108 **Hs** [270]	109 **Mt** [276]	110 **Ds** [281]	111 **Rg** [280]	112 **Cn** [285]	113 **Uut** [284]	114 **Uuq** [289]	115 **Uup** [288]	116 **Uuh** [293]	117 **Uus** [294]	118 **Uuo** [294]

Lanthanides	57 **La** 138.90547	58 **Ce** 140.116	59 **Pr** 140.90765	60 **Nd** 144.242	61 **Pm** [145]	62 **Sm** 150.36	63 **Eu** 151.964	64 **Gd** 157.25	65 **Tb** 158.92535	66 **Dy** 162.500	67 **Ho** 164.93032	68 **Er** 167.259	69 **Tm** 168.93421	70 **Yb** 173.054	71 **Lu** 174.9668
Actinides	89 **Ac** [227]	90 **Th** 232.03806	91 **Pa** 231.03588	92 **U** 238.02891	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]