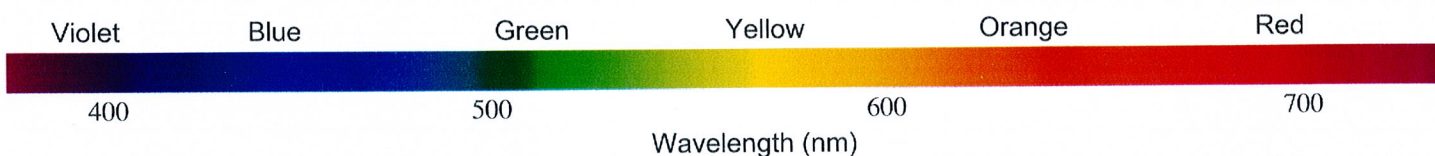Student Name: _Answer Key_　　Student ID# _____

Potentially Useful Information

Ideal Gas: $PV = nRT$ 　　　　$N_A = 6.0221 \times 10^{23}$ particles/mol 　　　Absolute T(K) = T(°C) + 273.15

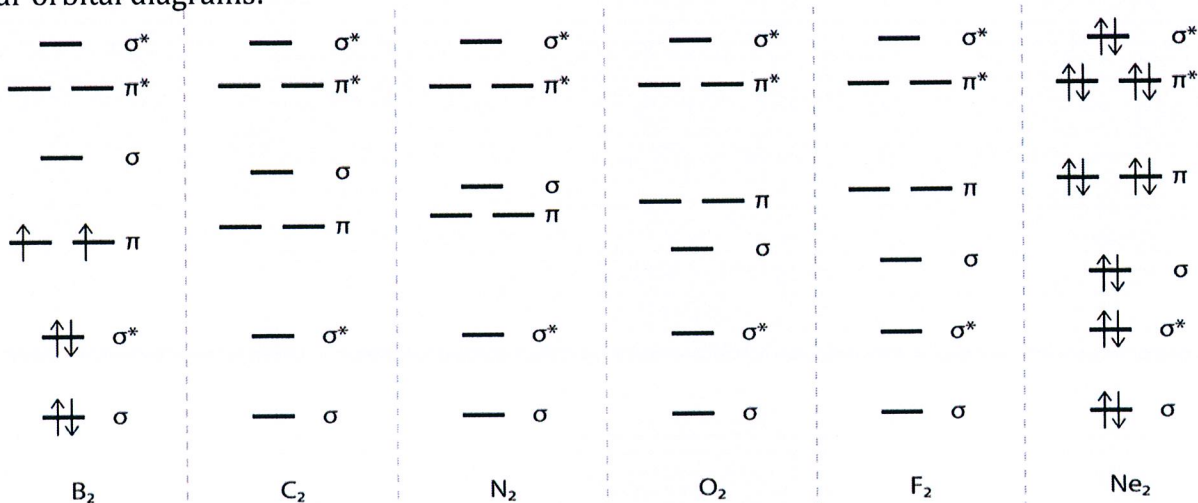$V_m = 22.414$ L mol^{-1} at STP (1 atm, 273.15 K) 　　　　$R = 0.08206$ L atm mol^{-1} K^{-1}

$$v_{rms} = \sqrt{\overline{v^2}} = \sqrt{\frac{3k_B T}{m}} = \sqrt{\frac{3RT}{M}}$$

Particle in a 1D box:
$$E_n = \frac{h^2 n^2}{8mL^2}; \quad n = 1, 2, 3, \dots$$

| Violet | Blue | Green | Yellow | Orange | Red |

Wavelength (nm): 400　　500　　600　　700

$\lambda v = c$ 　$E_{photon} = hv$ 　$c = 2.9989 \times 10^8 \ m \ s^{-1}$ 　$h = 6.62608 \times 10^{-34} \ J \ s$ 　$p = mv$ 　$E_k = \frac{mv^2}{2} = \frac{p^2}{2m}$

Molecular orbital diagrams:

	Na	K	Rb	Cl	Br	I
Ionization Energy (kJ/mol)	496	419	403	1251	1140	1008
Electron Affinity (kJ/mol)	53	48	47	349	325	295

Only scientific calculators may be used on this exam; graphing calculators (or any calculator with a "Solve" function the capability to store ASCII/text data, etc.) are strictly prohibited. The use of unauthorized materials will result in a grade of zero on the exam. At instructor discretion, students found cheating may also be reported to the UC Berkeley Center for Student Conduct.

1. 1.54 g each of Ne and Ar are placed in a 114.9 mL container at 100°C. What is the partial pressure in atm of Ne in the container?

A) 5.45   B) 786.28   C) 210.96   D) 20.32   E) 10.27

$Ne \; 20 \, g/mol \to 7.7 \times 10^{-2} \, mol$ moles $Ne = 2 \times$ moles Ar

$Ar \; 40 \, g/mol \quad 3.85 \times 10^{-2} \, mol$ $P_{tot} = 3 \times 10^{+1} \, atm$ $30 \, atm \times \frac{2}{3}(P_{Ne}) = 20.32 \, atm$

2. For an ideal gas, which of the following statements is not true?

A) At constant temperature, pressure is proportional to density

B) At constant density, pressure is proportional to T

C) At constant temperature and number of moles, volume is proportional to pressure

D) At standard pressure and temperature, volume is proportional to the number of moles

E) None of the above

Consider the following reaction for questions 3 and 4:

A

Pink Solution
Steric #6

B

Blue Solution
Steric #4

HCl →
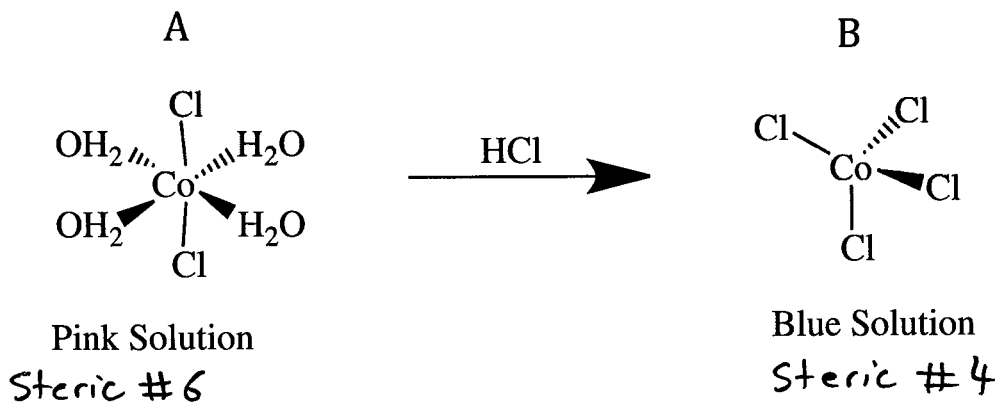
3. In the reaction above the hybridization around the cobalt (Co) atom changes from:

A) $sp^6 \to sp^3$ B) $sd^6 \to sd^3$ C) $sp^3d^2 \to sp^3$ D) $sp^3d^2 \to sd^3$ E) No change

4. What wavelength of light could be used to excite complex A from the HOMO (Highest Occupied Molecular Orbital) to the LUMO (Lowest Unoccupied Molecular Orbital)?

A) Radio Wave ($\lambda \sim 1m$)   B) IR   C) Pink   D) Red   E) Blue

A pink solution absorbs blue light

5. If 1 atm of CH_4 (g) and 1 atm of O_2 (g) (a total pressure of 2 atm) react to form CO_2 (g) and H_2O (g) at constant temperature and volume what is the pressure of the product mixture?

A) 0 atm   B) 0.5 atm   C) 1.0 atm   D) 1.5 atm   E) 2.0 atm

1 to 1 molar ratios and all gas phase so

2 atm in → 2 atm out

2

6. One mole of C_{60}, buckminsterfullerene molecules decomposes to form carbon atoms. How many moles of carbon atoms are formed?
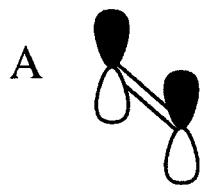
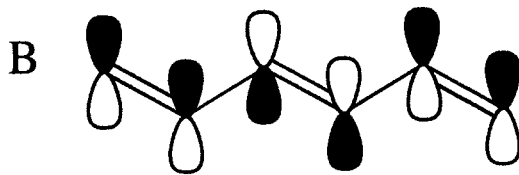A) 6.0×10^{23} B) 1.0×10^{22} C) 60   D) 1.0   E) 1.7×10^{-2}
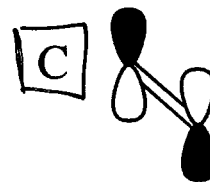
1 mole C_{60} = 60 moles C_1

7. Assuming that delocalized π-systems can be modeled in the same way as particle-in-a-box problems, which of the following molecular orbitals (with delocalized π-systems) has the highest energy?
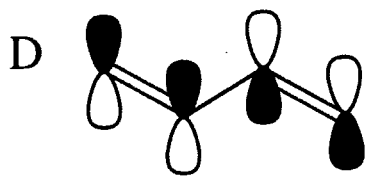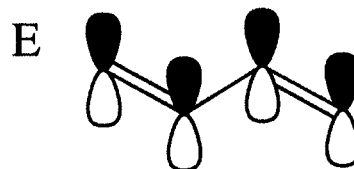
A   n=1 L=1

B   n=3 L=5

C   n=2 L=1

$E = \dfrac{n^2}{L^2}$

D   n=2 L=3

E   n=1 L=3

8. Which of the following molecules and molecular ions would experience an increase in paramagnetism through loss of an electron?

A) F_2 B) O_2 C) O_2^+ D) N_2^+ E) N_2^-

Use MO diagrams

9. Considering molecular orbital theory, which of the following has the weakest bond?
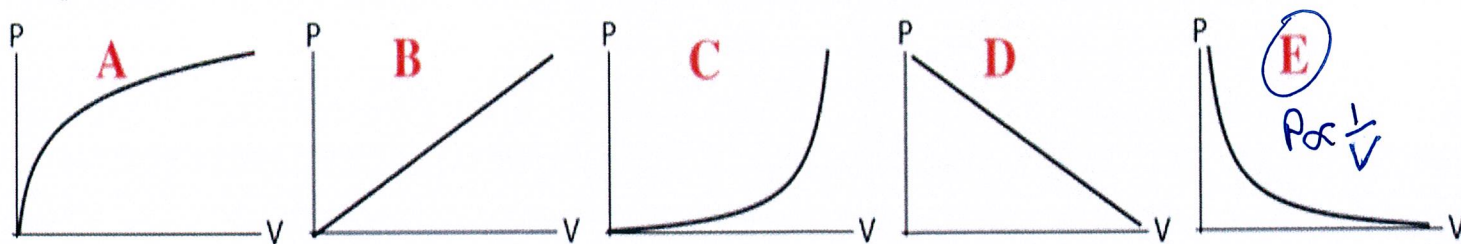
A) F_2 B) O_2 C) O_2^+ D) N_2^+ E) N_2^-

Use MO diagrams

10. Which graph depicts the dependence of pressure on volume for dilute He (g) at a constant temperature?

A   B   C   D   E

$P \propto \frac{1}{V}$

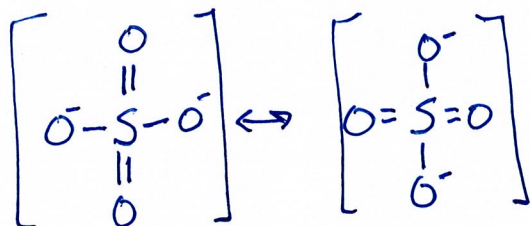11. What is the bond order of the S-O bonds in SO_4^{2-}?

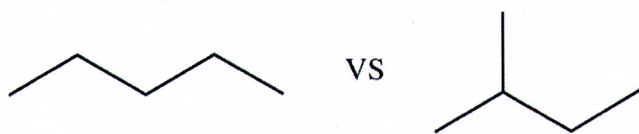A) 0.0   B) 0.5   C) 1.0   D) 1.5   E) 2.0

12. How many structural isomers (not counting stereoisomers) of C_4H_9Cl exist? Two structural isomers of pentane (C_5H_{12}) are shown below as an example:

VS

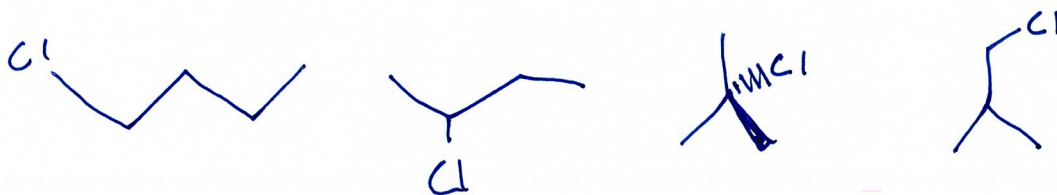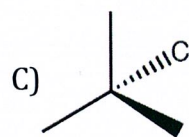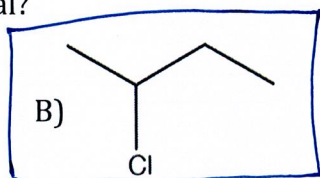A) 2   B) 3   C) 4   D) 5   E) 6

Bonus Question!
Everyone gets a point!

13. Which of the following is chiral?

A)

B)

C)

D) All of the above   E) None of the above

Bonus Question!
Everyone gets a point!

4 groups: $-H$, $-Cl$, $-CH_3$, $-CH_2CH_3$

4

14. A flask of fixed volume contains oxygen *atoms* at 6.00 atm pressure. What is the new pressure when all the atoms react to form O_3 molecules at constant temperature?

A) 1.0 atm   B) 1.3 atm   C) 1.5 atm   D) 2.0 atm   E) 2.3 atm
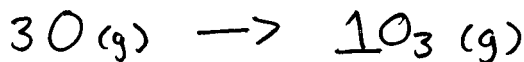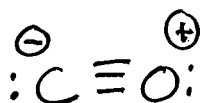
$3 O_{(g)} \longrightarrow 1 O_3 {(g)}$ 3:1 mole ratio $PV = nRT$

directly
proportional

15. What is the formal charge on the carbon in CO?

A) -2   B) -1   C) 0   D) +1   E) +2

$:\overset{\ominus}{C} \equiv \overset{\oplus}{O}:$

16. Helium gas taken from a nuclear experiment contains ^{3}He and ^{4}He. One mole of gas weighs 3.75 g and has a pressure of 1 atm inside a fixed volume. What is the partial pressure of ^{3}He?

A) 1.25 atm   B) 0.75 atm   C) 0.50 atm   D) 0.25 atm   E) 0.0125 atm

g/mol   moles ^{4}He

$3x + 4(1-x) = 3.75g$ 0.25 moles ^{3}He   0.25 : 0.75

moles
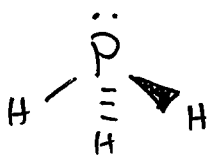^{3}He $3x + 4 - 4x = 3.75g$ 0.75 moles ^{4}He   mole ratio

$-x = -0.25$

17. Which is the proper ordering of the following elements from highest ionization energy to lowest?

A) Na, Mg, Si, S, Ar   B) Ar, Na, Si, S, Mg   C) Ar, S, Si, Mg, Na   D) Mg, Na, Si, Ar, S   E) Si, S, Ar, Na, Mg

nobel gas (high IE)

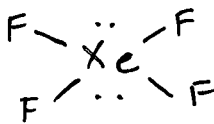18. Which of the following molecules has a central atom with sp^3 hybridization?

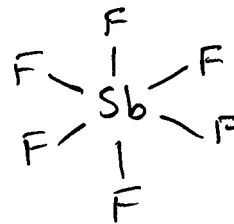A) PH$_3$ B) BeF$_2$ C) XeF$_4$ D) SF$_4$ E) SbF$_6^-$

sp^3 sp sp^3d^2 sp^3d sp^3d^2

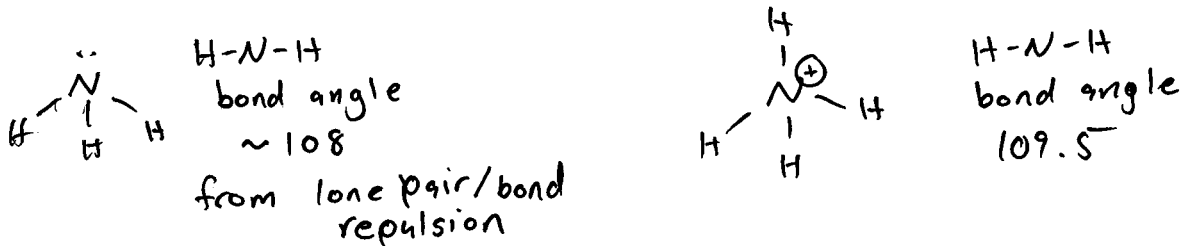**19.** How does the H-N-H bond angle change when NH_3 is protonated to NH_4^+?

| A) Increases | B) Decreases | C) No change | D) All of the above | E) None of the above |

[handwritten:]
H-N-H
bond angle
~108
from lone pair/bond
repulsion

H-N-H
bond angle
109.5

20. What is the steric number and electron pair configuration about tellurium in TeF_4?

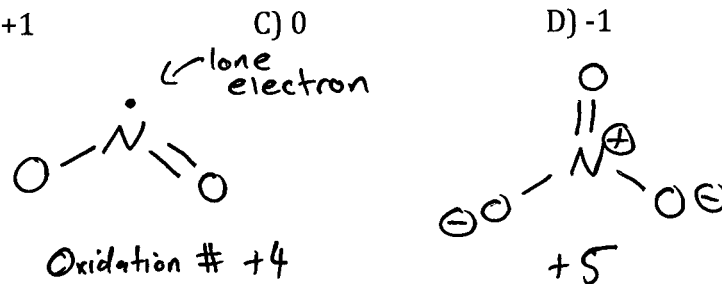A) 2, linear   B) 3, trigonal planar   C) 4, tetrahedral   D) 5, trigonal bipyramid   E) 6, octahedral
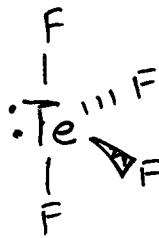
21. Which of the following molecules does not have a dipole moment?

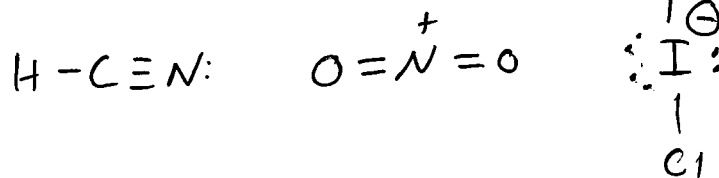A) H_2CO B) PCl_3 C) XeF_4 D) CH_2Cl_2 E) IF_3

[handwritten:] no dipole

22. By how much does the oxidation number for Nitrogen change when NO_2 is oxidized to NO_3^-?

A) +2   B) +1   C) 0   D) -1   E) -2

[handwritten:]
lone electron
Oxidation # +4
+5

23. Which has a linear structure?

A) HCN   B) NO_2^+ C) ICl_2^- D) A, B, and C   E) None

[handwritten:]
H−C≡N: O=N=O

24. How much energy is required for a mole each of atomic K and Br atoms to form ionic K^+ and Br^-?

A) 94 kJ   B) 325 kJ   C) 419 kJ   D) 744 kJ   E) 1188 kJ

Ionization Energy of K: 419 kJ
- Electron Affinity of Br: 325 kJ
_____
                         94 kJ

25. Which of the following has the strongest bond?

A) O_2^{2-} B) O_2^- C) O_2 D) O_2^+ E) O_2^{2+}

B.O. 1   B.O. 1.5   B.O. 2   B.O. 2.5   B.O. 3

26. Which of the following is the correct Lewis structure for HCN?

A
$H-C\equiv N :$

B
$H=N=C :$

C
$H=C=N :$

D
$H-N\equiv C :$
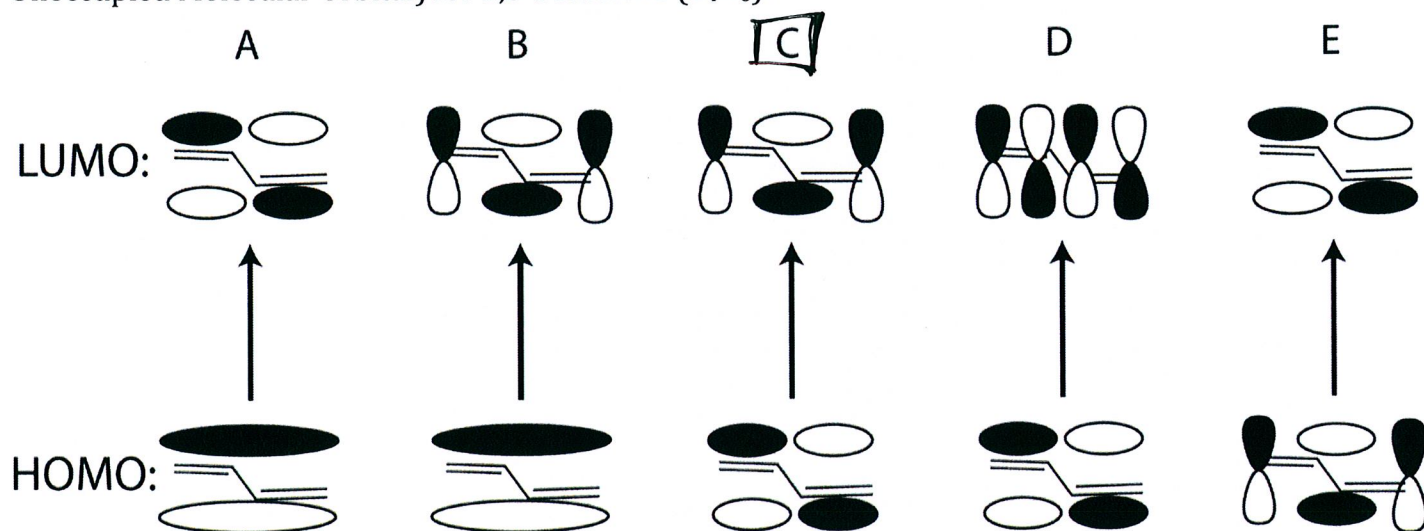
E
$H-C=N$
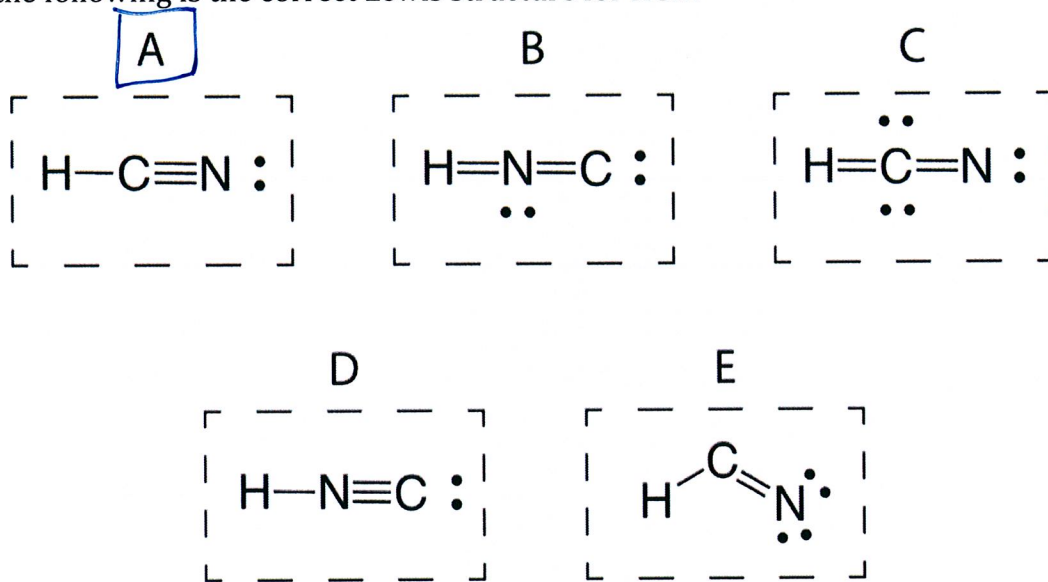
27. Which has the highest average speed?

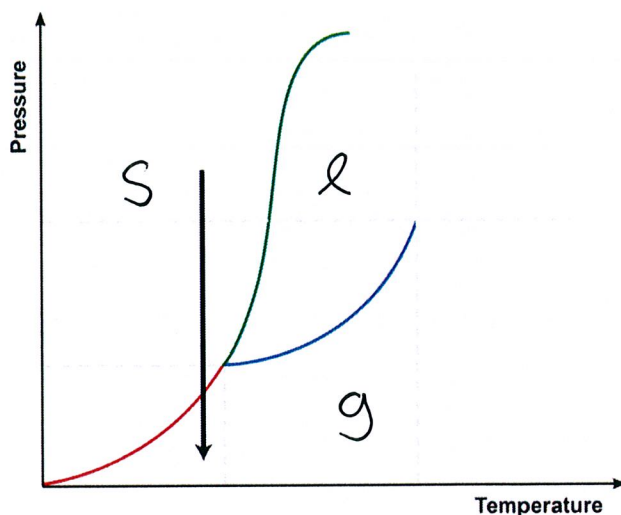A) Ne at 100 K   B) Ar at 100 K   C) Ar at 212 K   D) Br_2 at 212 K   E) Br_2 at 298 K

$\sqrt{\dfrac{100}{20}}$ $\sqrt{\dfrac{100}{40}}$ $\sqrt{\dfrac{212}{40}}$ $\sqrt{\dfrac{212}{160}}$ $\sqrt{\dfrac{298}{160}}$

7

28. Which of the following shows the HOMO (Highest Occupied Molecular Orbital) to LUMO (Lowest Unoccupied Molecular Orbital) for 1,3-butadiene (C_4H_6)?

A   B   [C]   D   E

LUMO:

HOMO:

29. What phase transition is depicted in the phase diagram below?

A) Melting   B) Freezing   C) Condensation   [D] Sublimation   E) Deposition

30. In order to ensure that the Scantron machine is calibrated bubble in A as your answer for 30.