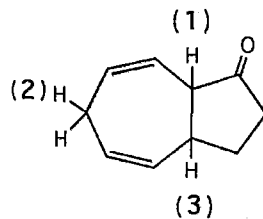


Atomic mass (u): H = 1.01, O = 16.0, Ne = 20.2, S = 32.1  
 $1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$   
 Gas constant  $R = 0.0821 \text{ atm L mol}^{-1} \text{ K}^{-1} = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$   
 Planck's constant  $h = 6.626 \times 10^{-34} \text{ J s}$   
 Speed of light  $c = 3.0 \times 10^8 \text{ m/s}$   
 Faraday constant  $F = 96485 \text{ C/mol}$   
 $\log 2 = 0.301, \log 3 = 0.477, \ln 2 = 0.693$

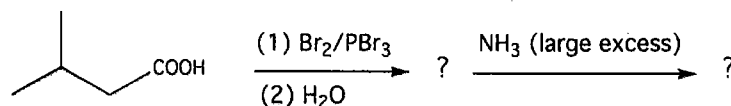
第一部分單選題：共 25 題，每題 2 分，答錯不倒扣。

- How many significant figures should be retained in the result of the following calculation?  
 $12.00000 \times 0.9893 + 13.00335 \times 0.0107$   
 (A) 3            (B) 4            (C) 5            (D) 6            (E) 7
- When the redox reaction in basic solution:  $\text{NO}_2^-(aq) + \text{Al}(s) \rightarrow \text{NH}_3(aq) + \text{AlO}_2^-(aq)$  is balanced using the smallest whole-number coefficients, the coefficient of  $\text{H}_2\text{O}$  is  $x$  and the sum of all coefficients is  $y$ . What are  $x$  and  $y$ ?  
 (A)  $x = 2, y = 9$     (B)  $x = 1, y = 8$     (C)  $x = 1, y = 9$     (D)  $x = 2, y = 8$   
 (E)  $x = 2, y = 10$
- Which of the following triglycerides would you most expect to be a liquid and the most healthy to use in cooking?  
 (A) saturated fat  
 (B) *trans*-monosaturated fat  
 (C) *trans*-polyunsaturated fat  
 (D) *cis*-monounsaturated fat  
 (E) *cis*-polyunsaturated fat
- How many of the following exhibit resonance?  
 $\text{O}_3, \text{OCl}_2, \text{NF}_3, \text{N}_2\text{O}, \text{CCl}_4, \text{CH}_3\text{NCO}, \text{O}_2\text{F}_2$   
 (A) 1            (B) 2            (C) 3            (D) 4            (E) 5
- Consider the following diatomic species (molecules and ions):  
 $\text{B}_2, \text{C}_2^{2-}, \text{OF}, \text{O}_2^-, \text{N}_2^+, \text{NO}^+, \text{F}_2$   
 The number of the species which are diamagnetic is  $x$ . The number of the species whose bond order is expected to decrease upon removing an electron is  $y$ . What is  $(x + y)$ ?  
 (A) 4            (B) 5            (C) 6            (D) 7            (E) 8
- How many of the following statements are NOT TRUE?  
 (i) The Group 3A elements are all metals.  
 (ii) Alkaline earth metals react less vigorously with water than do alkali metals.  
 (iii) Salts can consist of hydrogen.  
 (iv) Because Li is a stronger reducing agent than K and Na in aqueous solution, it reacts more quickly with water than K and Na.  
 (A) 0            (B) 1            (C) 2            (D) 3            (E) 4

7. Which sequence correctly ranks the following protons in order of increasing acidity?



- (A)  $1 < 2 < 3$       (B)  $2 < 3 < 1$       (C)  $3 < 1 < 2$       (D)  $3 < 2 < 1$   
 (E)  $2 < 1 < 3$
8. Which has the greatest molar heat of combustion?  
 (A) *trans*-1,2-dimethylcyclopentane  
 (B) *cis*-1,2-dimethylcyclopentane  
 (C) *trans*-1,3-dimethylcyclopentane  
 (D) methylcyclohexane  
 (E) cycloheptane
9. Which of the following reagents is used to protect the amino group of the N-terminal residue in solution-phase peptide synthesis?  
 (A) benzyl chloroformate  
 (B) lithium diisopropyl amide  
 (C) phenyl isothiocyanate  
 (D) dicyclohexylcarbodiimide  
 (E) trifluoroacetic acid
10. What is the major end product of the following reaction series?



- (A) Ala      (B) Gly      (C) Leu      (D) Ile      (E) Val
11. Treatment of a peptide which contains disulfide linkages with peroxyformic acid yields a peptide which contains what new amino acid residue?  
 (A) cystine  
 (B) cysteic acid  
 (C) 4-hydroxyproline  
 (D)  $\gamma$ -alanine  
 (E) methioic acid
12. Which of the following groups contains the molecules that do not have a same point group?  
 (A)  $\text{CO}_2$  and  $\text{C}_2\text{H}_2$   
 (B)  $\text{PCl}_5$  and  $\text{BF}_3$   
 (C)  $\text{POCl}_3$  and  $\text{NH}_3$   
 (D)  $\text{SO}_2\text{F}_2$  and  $\text{H}_2\text{O}$   
 (E)  $\text{CH}_4$  and  $\text{XeF}_4$

13. Which of the following species is optically active?  
(A)  $\text{NH}_2\text{Cl}$  (B)  $\text{CO}_3^{2-}$  (C)  $\text{BrF}_4^-$  (D)  $\text{SiFCIBrI}$  (E)  $\text{HCN}$
14. What is the purpose of a moderator surrounding the uranium cylinder in a nuclear (fission) reactor core?  
(A) To slow down the neutrons  
(B) To accelerate the neutrons  
(C) To produce  $\alpha$  particles  
(D) To absorb  $\beta$  particles  
(E) To absorb the neutrons
15. Which of the following instruments is/are used to detect and measure radioactivity levels?  
I. Geiger counter  
II. Richter scale  
III. Seismic scale  
IV. Scintillation counter  
(A) I only (B) III only (C) I & IV (D) II & III (E) I, II, III & IV
16. How many of the following ligands are capable of linkage isomerism?  
 $\text{N}_3^-$ ,  $\text{NO}_2^-$ ,  $\text{NH}_3$ ,  $\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$ ,  $\text{OCN}^-$ ,  $\text{Cl}^-$ ,  $\text{H}_2\text{O}$ ,  $\text{SCN}^-$   
(A) 1 (B) 2 (C) 3 (D) 4 (E) 5
17. You analyze for pyridine ( $K_b$  is approximately  $10^{-9}$ ) by dissolving 0.1000 g of the complex in 100 mL of  $\text{H}_2\text{O}$  and titrating with a 0.01 M  $\text{HCl}$  solution. Which of the following indicators should be used to detect the endpoint? (Assume that the initial concentration of pyridine is approximately 0.01 M.)  
(A) thymol blue, pH range of color change = 8.0–9.6  
(B) methyl red, pH range of color change = 4.8–6.0  
(C) bromophenol blue, pH range of color change = 3.0–4.6  
(D) bromothymol blue, pH range of color change = 6.0–7.6  
(E) alizarin yellow, pH range of color change = 10.1–12.0
18. Which of the following is paramagnetic?  
(A)  $[\text{Co}(\text{NH}_3)_6]^{3+}$  (strong field)  
(B)  $[\text{Mn}(\text{CN})_6]^{4-}$  (strong field)  
(C)  $[\text{Cu}(\text{en})_3]^+$   
(D)  $[\text{Fe}(\text{CN})_6]^{4-}$  (strong field)  
(E)  $[\text{Zn}(\text{H}_2\text{O})_6]^{2+}$
19. Which of the following statements about biomolecules is TRUE?  
(A) Messenger RNA can be found in both the nucleus and the cytoplasm of each cell.  
(B) Nonpolar groups tend to face the outside of a protein in aqueous solution.  
(C) Nucleic acids are made of nucleotides joined together with amide bonds.  
(D) A glycosidic linkage in polysaccharides is an ester group.  
(E) Table sugar is formed from  $\beta$ -D-glucose and  $\beta$ -D-fructose.

20. Arrange the following species from lowest to highest ionization energy: O, O<sub>2</sub>, O<sub>2</sub><sup>-</sup>, O<sub>2</sub><sup>+</sup>.
- (A) O<sub>2</sub><sup>-</sup> < O<sub>2</sub> < O<sub>2</sub><sup>+</sup> < O  
 (B) O<sub>2</sub><sup>-</sup> < O<sub>2</sub> < O < O<sub>2</sub><sup>+</sup>  
 (C) O<sub>2</sub><sup>+</sup> < O<sub>2</sub><sup>-</sup> < O < O<sub>2</sub>  
 (D) O<sub>2</sub> < O<sub>2</sub><sup>-</sup> < O<sub>2</sub><sup>+</sup> < O  
 (E) O<sub>2</sub><sup>-</sup> < O < O<sub>2</sub> < O<sub>2</sub><sup>+</sup>
21. The molar mass of a solid as determined by freezing-point depression is 10% higher than the true molar mass. Which of the following experimental errors could *not* account for this discrepancy?
- (A) Before the solution was prepared, the container was rinsed with solvent and not dried.  
 (B) Some solid was left on the weighing paper.  
 (C) Not all the solid was dissolved.  
 (D) The solid dissociated slightly into two particles when it dissolved.  
 (E) More than the recorded amount of solvents was pipetted into the solution.
22. What is the formula for the compound that crystallizes with a cubic closed packed array of sulfur ions, and that contains zinc ions in 12.5% of the tetrahedral holes and aluminum ions in 50% of the octahedral holes?
- (A) ZnAlS<sub>4</sub>      (B) ZnAl<sub>2</sub>S<sub>4</sub>      (C) ZnAl<sub>4</sub>S<sub>2</sub>      (D) ZnAl<sub>2</sub>S<sub>2</sub>      (E) ZnAl<sub>4</sub>S<sub>8</sub>
23. Metal X has a body-centered cubic structure. If the atomic radius of X is R, what is the edge length of the unit cell?
- (A) 2 R      (B)  $\sqrt{2}$  R      (C)  $\frac{2}{3}\sqrt{3}$  R      (D)  $\frac{4}{3}\sqrt{3}$  R      (E)  $\sqrt{3}$  R
24. Samples of the gases H<sub>2</sub>(g) and SO<sub>2</sub>(g) have equal masses and are at the same temperature and pressure. Calculate the ratio of rates of impact with the walls (H<sub>2</sub>:SO<sub>2</sub>).
- (A) 180      (B) 32      (C) 5.6      (D) 1.0      (E) 0.18
25. Consider the following gas samples:

Sample M	Sample N
S <sub>2</sub> (g)	O <sub>2</sub> (g)
n = 1 mol	n = 2 mol
T = 800 K	T = 400 K
P = 0.20 atm	P = 0.40 atm

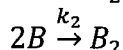
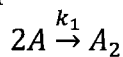
Which of the following statements is NOT TRUE?

- (A) Assuming identical intermolecular forces in the two samples, sample M should be more nearly ideal than sample N.  
 (B) The root-mean-square velocity of molecules in sample M is twice as large as the root-mean-square velocity of molecules in sample N.  
 (C) The average kinetic energy of the molecules in sample M is twice the average kinetic energy of the molecules in sample N.  
 (D) The fraction of molecules in sample M having kinetic energies greater than some high fixed value is larger than the fraction of molecules in sample N having kinetic energies greater than that same high fixed value.  
 (E) The volume of sample M is twice the volume of sample N.

第二部份單選題，共 10 題，每題 2 分，答錯倒扣 1/5 題分，未作答以 0 分計，倒扣至第二部份單選題 0 分為止。

26. A 0.100 g sample of the weak acid HA (molar mass = 100 g/mol) is dissolved in 500 g water. The freezing point of the resulting solution is  $-0.0056\text{ }^{\circ}\text{C}$ . Calculate the value of  $K_a$  for this acid. Assume molarity equals molality in this solution. (The molal freezing point depression constant  $K_f$  is  $1.86\text{ }^{\circ}\text{C/m}$ .)
- (A)  $1.0 \times 10^{-4}$  (B)  $1.7 \times 10^{-4}$  (C)  $2.5 \times 10^{-4}$  (D)  $2.0 \times 10^{-3}$  (E)  $1.0 \times 10^{-3}$

27. Two isomers (A and B) of a given compound dimerize as follows:



Both processes are known to be second order in the reactant, and  $k_1$  is known to be  $0.250\text{ M}^{-1}\text{ s}^{-1}$  at  $25\text{ }^{\circ}\text{C}$ . In a particular experiment A and B were placed in separate container at  $25\text{ }^{\circ}\text{C}$ , where  $[A]_0 = 1.00 \times 10^{-2}\text{ M}$  and  $[B]_0 = 2.5 \times 10^{-2}\text{ M}$ . After each reaction had progressed for 3.00 min,  $[A] = 3.00 [B]$ . In this case the rate laws are define as follows:

$$\text{Rate} = -\frac{d[A]}{dt} = k_1[A]^2$$

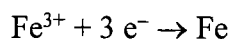
$$\text{Rate} = -\frac{d[B]}{dt} = k_2[B]^2$$

The concentration of  $A_2$  after 3.00 min is  $x\text{ M}$ . The half-life for the experiment involving B is  $y\text{ s}$ . What are the values of  $x$  and  $y$ ?

- (A)  $x = 1.6 \times 10^{-3}$ ,  $y = 18.2$   
 (B)  $x = 3.1 \times 10^{-3}$ ,  $y = 18.2$   
 (C)  $x = 1.6 \times 10^{-3}$ ,  $y = 36.4$   
 (D)  $x = 3.1 \times 10^{-3}$ ,  $y = 36.4$   
 (E)  $x = 1.6 \times 10^{-3}$ ,  $y = 400$
28. Given the following two standard reduction potentials,

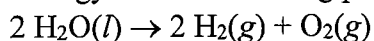


Determine for the standard reduction potential of the half-reaction



- (A)  $-0.33\text{ V}$  (B)  $-0.036\text{ V}$  (C)  $-0.11\text{ V}$  (D)  $0.11\text{ V}$  (E)  $0.33\text{ V}$
29. The observed solubility of the salt MX in 4.0 M strong acid is  $2.30 \times 10^{-3}\text{ M}$ . The  $K_a$  value for the acid HX is  $1.00 \times 10^{-9}$ . Calculate the value of  $K_{sp}$  for the salt MX.
- (A)  $1.3 \times 10^{-3}$  (B)  $1.3 \times 10^{-6}$  (C)  $5.3 \times 10^{-6}$  (D)  $1.3 \times 10^{-15}$  (E)  $5.3 \times 10^{-15}$
30. A galvanic cell is constructed with copper electrodes and  $\text{Cu}^{2+}$  in each compartment. In one compartment,  $[\text{Cu}^{2+}] = 2.4 \times 10^{-3}\text{ M}$ , and in the other compartment,  $[\text{Cu}^{2+}] = 3.0\text{ M}$ . Calculate the potential for this cell at  $25\text{ }^{\circ}\text{C}$ . The standard reduction potential for  $\text{Cu}^{2+}$  is  $+0.34\text{ V}$ .
- (A)  $0.43\text{ V}$  (B)  $-0.43\text{ V}$  (C)  $0.092\text{ V}$  (D)  $-0.092\text{ V}$  (E)  $0.77\text{ V}$

31. The standard enthalpy of formation of  $\text{H}_2\text{O}(l)$  at 300 K is  $-286 \text{ kJ/mol}$ . Calculate the change in internal energy for the following process at 300 K and 1 atm:



- (A) 278.5 kJ (B) 282.3 kJ (C) 289.7 kJ (D) 564.5 kJ (E) 579.5 kJ
32. A 0.50 M solution of the BHA has a pH of 7.50 at 25 °C, where B is a weak base and  $\text{A}^-$  is the anion of the weak acid HA. If the  $K_b$  value for B is  $1.0 \times 10^{-5}$ , what is the  $K_a$  value for HA?
- (A)  $1.0 \times 10^{-6}$  (B)  $2.0 \times 10^{-6}$  (C)  $1.0 \times 10^{-10}$  (D)  $1.0 \times 10^{-5}$  (E)  $2.0 \times 10^{-5}$
33. What is  $[\text{OH}^-]$  in a  $2.00 \times 10^{-7} \text{ M}$  solution of  $\text{Ca}(\text{OH})_2$  at 25 °C?
- (A)  $2.41 \times 10^{-7} \text{ M}$  (B)  $4.00 \times 10^{-7} \text{ M}$  (C)  $4.24 \times 10^{-7} \text{ M}$  (D)  $4.41 \times 10^{-7} \text{ M}$   
(E)  $5.00 \times 10^{-7} \text{ M}$
34. The heat of vaporization of water at the normal boiling point, 373 K, is 40.7 kJ/mol. The specific heat capacity of liquid water is  $75.4 \text{ J K}^{-1} \text{ mol}^{-1}$  and of gaseous water is  $36.4 \text{ J K}^{-1} \text{ mol}^{-1}$ . Assume that these values are independent of temperature. What is the heat of vaporization of water at 288 K?
- (A) 44.0 kJ/mol (B) 50.2 kJ/mol (C) 37.4 kJ/mol (D) 31.2 kJ/mol  
(E) 40.7 kJ/mol
35. The atomic mass is 2.01410 u for  ${}^2_1\text{H}$ . The masses are 0.000549 u for electron, 1.00728 u for proton, and 1.00866 u for neutron. What is the binding energy per nucleon for  ${}^2_1\text{H}$ ?
- (A) 1.12 MeV (B) 1.42 MeV (C) 2.24 MeV (D) 2.83 MeV (E) 5.66 MeV

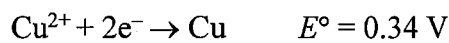
第三部份多重選擇題，共 10 題，每題 3 分，各題之選項獨立判定，每答對一個選項得 1/5 題分，每答錯一個選項倒扣 1/5 題分，所有選項均未作答者，該題以 0 分計，倒扣至第三部份多重選擇題 0 分為止。

36. Consider 150 J of heat added to 40.4 g of Ne in a closed container at 0 °C and 1 atm. If the heat is transferred at constant pressure, which of the following statements are TRUE? (Assume that the gases behave ideally.)
- (A) The final temperature will increase.  
(B) The change in enthalpy ( $\Delta H$ ) is 150 J.  
(C) The change in internal energy ( $\Delta E$ ) is 90 J.  
(D) The work ( $w$ ) is  $-60 \text{ J}$ .  
(E) If the heat is transferred at constant volume in the above process, the change in enthalpy ( $\Delta H$ ) will be 250 J.

37. One mole of an ideal gas undergoes an isothermal reversible expansion at 300 K. During the process, the system absorbs 750 J of heat from the surroundings. When this gas is compressed to the original state in one step isothermally, twice as much work is done on the system as was performed on the surroundings in the expansion. Which of the following statements are TRUE?

- (A)  $\Delta S_{\text{sys}}$  for the one-step isothermal compression is 2.5 J/K.  
 (B)  $\Delta S_{\text{surr}}$  for the one-step isothermal compression is 5.0 J/K.  
 (C)  $\Delta S_{\text{univ}}$  for the reversible isothermal expansion is zero.  
 (D)  $\Delta S_{\text{univ}}$  for the overall process (expansion and compression) is zero.  
 (E)  $\Delta S_{\text{surr}}$  for the overall process (expansion and compression) is -2.5 J/K.

38. Consider the standard galvanic cell at 25 °C based on the following half-reaction:



The electrodes in this cell are Ag(s) and Cu(s). Which of the following changes will make the cell potential decrease?

- (A)  $\text{CuSO}_4(\text{s})$  is added to the copper half-cell compartment (assume no volume change).  
 (B)  $\text{NH}_3(\text{aq})$  is added to the copper half-cell compartment.  
 (C)  $\text{NaCl}(\text{s})$  is added to the silver half-cell compartment.  
 (D) Water is added to both half-cell compartments until the volume of solution is doubled.  
 (E) The silver electrode is replaced with a platinum electrode. ( $\text{Pt}^{2+} + 2\text{e}^{-} \rightarrow \text{Pt}$ ,  $E^{\circ} = 1.19 \text{ V}$ )
39. Which of the following statements about nuclear reaction and stability are TRUE?
- (A) A radioactive nuclide that decays from  $1.00 \times 10^{10}$  atoms to  $2.5 \times 10^9$  atoms in 10.0 mins has a half-life of 5.0 mins.  
 (B) Nuclides with large Z values are often observed to be  $\alpha$ -particle producers.  
 (C) As Z increases, nuclides need a greater proton-to-neutron ratio for stability.  
 (D) Those "light" nuclides that have twice as many neutrons as protons are expected to be stable.  
 (E) If more than one neutron from each fission event causes another fission event, the fission situation is described as supercritical.
40. Which of the following statements about "The Bohr Model" and "Particle in a Box" are TRUE?
- (A) A function of the type  $A \cos(Lx)$  can be an appropriate solution for the particle in a one-dimensional box.  
 (B) If the wavelength of light necessary to promote an electron from the ground state to the first excited state is  $\lambda$  in a one-dimensional box, then the wavelength of light necessary to promote an electron from the first excited state to the third excited state will be  $\lambda/2$ .  
 (C) The total probability of finding a particle in a one-dimensional box (length is L) in energy level  $n = 4$  between  $x = L/4$  and  $x = L/2$  is 25%.  
 (D) For an electron trapped in a one-dimensional box, as the length of the box increases, the spacing between energy levels will increase.  
 (E) Assume that a hydrogen atom's electron has been excited to the  $n = 5$  level. When this excited atom loses energy, 10 different wavelengths of light can be emitted.

41. Iodine, like most substances, exhibits only three phases: solid, liquid, and vapor. The triple point of iodine is at 90 torr and 115 °C. Which of the following statements concerning liquid I<sub>2</sub> are NOT TRUE?
- (A) I<sub>2</sub>(l) cannot exist at 1 atmosphere pressure.  
 (B) I<sub>2</sub>(l) cannot exist above 115 °C.  
 (C) I<sub>2</sub>(l) is denser than I<sub>2</sub>(g).  
 (D) I<sub>2</sub>(l) can have a vapor pressure greater than 90 torr.  
 (E) I<sub>2</sub>(l) cannot exist at a pressure of 10 torr.

42. The following results were obtained at 600 K for the decomposition of ethanol on alumina (Al<sub>2</sub>O<sub>3</sub>) surface,

$$\text{C}_2\text{H}_5\text{OH}(g) \rightarrow \text{C}_2\text{H}_4(g) + \text{H}_2\text{O}(g)$$

$t$ (s)	$P_{\text{total}}$ (torr)
0	250
10	265
20	280
30	295
40	310
50	325

Which of the following statements are TRUE?

- (A) At  $t = 80$  s,  $P_{\text{total}}$  is 370 torr.  
 (B) The rate constant is 90 torr/min.  
 (C) This a first order reaction.  
 (D) At  $t = 300$  s,  $P_{\text{total}}$  is 700 torr.  
 (E) At  $t = 100$  s, the partial pressure of ethanol is 100 torr.
43. Consider a buffered solution containing CH<sub>3</sub>NH<sub>3</sub>Cl and CH<sub>3</sub>NH<sub>2</sub>. Which of the following statements concerning this solution are TRUE? ( $K_a$  (CH<sub>3</sub>NH<sub>3</sub><sup>+</sup>) =  $2.0 \times 10^{-11}$ )
- (A) A solution consisting of 0.10 M CH<sub>3</sub>NH<sub>3</sub>Cl and 0.10 M CH<sub>3</sub>NH<sub>2</sub> would have a higher buffering capacity than one containing 1.0 M CH<sub>3</sub>NH<sub>3</sub>Cl and 1.0 M CH<sub>3</sub>NH<sub>2</sub>.  
 (B) If [CH<sub>3</sub>NH<sub>2</sub>] > [CH<sub>3</sub>NH<sub>3</sub><sup>+</sup>], then the pH is larger than the pK<sub>a</sub> value of CH<sub>3</sub>NH<sub>3</sub><sup>+</sup>.  
 (C) Adding more [CH<sub>3</sub>NH<sub>3</sub>Cl] to the initial buffer solution will increase the pH.  
 (D) If [CH<sub>3</sub>NH<sub>2</sub>] > [CH<sub>3</sub>NH<sub>3</sub><sup>+</sup>], then pH > 10.50.  
 (E) If [CH<sub>3</sub>NH<sub>2</sub>] = [CH<sub>3</sub>NH<sub>3</sub><sup>+</sup>], then pH = 3.30.
44. Which of the following statements are TRUE?
- (A) Octahedral Ni<sup>2+</sup> complexes are more appropriate than octahedral Cr<sup>2+</sup> complexes to be used to determine whether a ligand is a strong-field or a weak-field ligand.  
 (B) The fulminate ions (CNO<sup>-</sup>) can have three different Lewis structures in which all the N atoms have a same formal charge.  
 (C) Cobalt is a component of vitamin B12, which is essential for the metabolism of carbohydrates, fats, and proteins.  
 (D) <sup>2</sup>H, <sup>10</sup>B, <sup>15</sup>N, <sup>17</sup>O, and <sup>19</sup>F are all NMR active nuclides.  
 (E) Both Ir(NH<sub>3</sub>)<sub>3</sub>Cl<sub>3</sub> and [Ni(H<sub>2</sub>O)<sub>4</sub>(NO<sub>2</sub>)<sub>2</sub>] exhibit geometric isomerism.



45. Consider 1.0 mole of a monatomic ideal gas in a container fitted with a piston. The initial conditions are  $V = 5.0$  L and  $P = 4.0$  atm at some constant  $T$ . These two processes are performed isothermally:

- (a) The external pressure is suddenly changed to 2.0 atm to allow expansion of the gas.
- (b) Followed by process (a), the external pressure suddenly changes back to 4.0 atm to compress the gas.

Which of the following statements about these two processes are NOT TRUE?

- (A) In process (a), expansion of the gas is spontaneous.
- (B) In process (b), compression of the gas is nonspontaneous.
- (C) The sign of free energy change ( $\Delta G$ ) can be used to predict spontaneity of these two processes.
- (D) In process (a), the change of internal energy ( $\Delta E$ ) is zero during the gas expansion.
- (E) In process (b), the sign of  $\Delta S_{\text{surr}}$  is negative during the gas compression.