

1.) For a container with gaseous H_2 , He, and Ne, which of the following statements is completely true?

- A) The H_2 will have an average speed lower than the He because H_2 is made up of 2 atoms. (number of atoms is irrelevant)
- B) Any He atom will be faster than any Ne atom. (statistics doesn't mix with 'any')
- C) The kinetic energy of any He atom will be the same as that of any Ne atom. (see b)
- D) There will be more H_2 molecules with a speed equal to v_{rms} at lower temperatures than at higher temperatures. (lower temp = smaller standard deviation)**
- E) H_2 and Ne will have the same standard deviation around their v_{rms} as long as they are at the same temperature. (more weight or temp = wider deviation)

2.) At the triple point of water, which of the following has the greatest entropy?

- A) 1 mol water vapor
- B) 2 mol water vapor**
- C) 1 mol ice
- D) 1 mol liquid water
- E) 2 mol ice

3.) A system of argon (Ar) gas confined to a flexible container at STP (1 atm, 273 K) expands isothermally against an external pressure of 1 atm. Which of the following is true for the system? **MARK ALL THAT APPLY.**

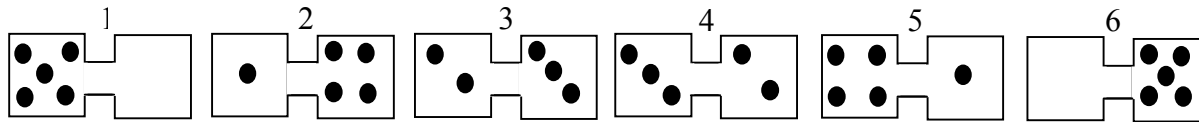
- A) $w = 0$
- B) $w > 0$
- C) $w = q$
- D) $w = -q$**
- E) $w = \Delta E$

4.) The critical point of water (H_2O) occurs at 374°C and 218.0 atm. The liquid vaporizes to gas at 1.00 atm and 100°C . At what pressure are water liquid and vapor at equilibrium at 250°C ?

- A) 0.00 atm
- B) 0.40 atm
- C) 1.00 atm
- D) 185.00 atm**
- E) 251.00 atm

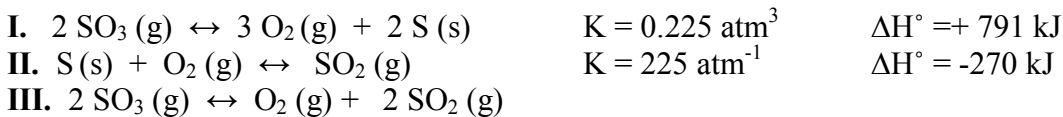
Only one answer between 218 and 1 atm.

5.) Which process is accompanied by the smallest **increase** in entropy?



- A) 1 → 2
- B) 1 → 3
- C) 2 → 6
- D) 3 → 4
- E) 5 → 6

For questions 6-9, refer to the following equations.



6.) What is the equilibrium constant for a mixture of O_2 , SO_3 and SO_2 gas (rxn. III)?

$$K_3 = \frac{[\text{O}_2][\text{SO}_2]^2}{[\text{SO}_3]^2}$$

$$K_1 = \frac{[\text{S}]^2[\text{O}_2]^3}{[\text{SO}_3]^2}$$

$$K_3 / K_1 = \frac{[\text{SO}_2]^2 / [\text{S}]^2 [\text{O}_2]^2}{[\text{SO}_3]^2}$$

$$= K_2^2$$

$$\therefore K_3 = K_1 \times K_2^2$$

$$= 0.225 \times 225 \times 225 = 1.1 \times 10^4$$

- A) 75.5 atm
- B) 112 atm
- C) **1.1×10^4 atm**
- D) 2.5×10^{-5} atm
- E) 0.775 atm

7.) What change has occurred if the value of K for rxn I is found to be 0.552 atm^3 ?

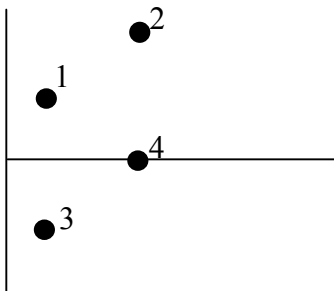
- A) **An increase in temperature.**
- B) A decrease in temperature.
- C) An increase in pressure.
- D) An increase in volume.
- E) Cannot be determined.

8.) What is ΔH° for reaction III?

$$\begin{aligned} \text{I} + 2(\text{II}) &= \text{III} \\ 791 + 2(-270) &= 251 \text{ kJ} \end{aligned}$$

- A) 333 kJ
- B) 251 kJ**
- C) 1.7×10^3 kJ
- D) 5 kJ
- E) 76 kJ

9) The correct plot for $\ln K$ vs $1/T$ for reaction I would pass through which pair of points?



- A) 1-2
- B) 1-4**
- C) 3-4
- D) 2-4
- E) 1-3

10) Which of the following equilibria will shift to the left in response to a decrease in volume?

- A) $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \leftrightarrow 2 \text{HCl}(\text{g})$
- B) $2 \text{SO}_3(\text{g}) \leftrightarrow 2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g})$**
- C) $\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \leftrightarrow 2 \text{NH}_3(\text{g})$
- D) $4 \text{Fe}(\text{s}) + 3 \text{O}_2(\text{g}) \leftrightarrow 2 \text{Fe}_2\text{O}_3(\text{s})$
- E) $2\text{HI}(\text{g}) \leftrightarrow \text{H}_2(\text{g}) + \text{I}_2(\text{g})$

11) Which intermolecular forces predominate in the condensation of mercury?

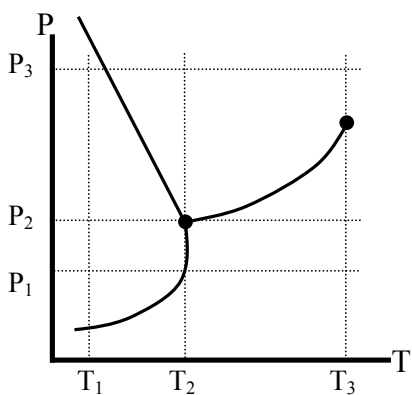
- A) H-bonding
- B) Dipole-Dipole
- C) Dispersion**
- D) Ion-Ion
- E) Ion-Dipole

12) What is the change in the internal energy (in J) of a system that releases 1000 J of heat and does 225 J of work on the surroundings?

$$\begin{aligned}\Delta E &= q + w = -1000 + (-225) \\ &= -1225\end{aligned}$$

- A) -10,155
- B) -1225**
- C) -775
- D) 775
- E) 1225

Consider the phase diagram below when answering the questions 13-15.



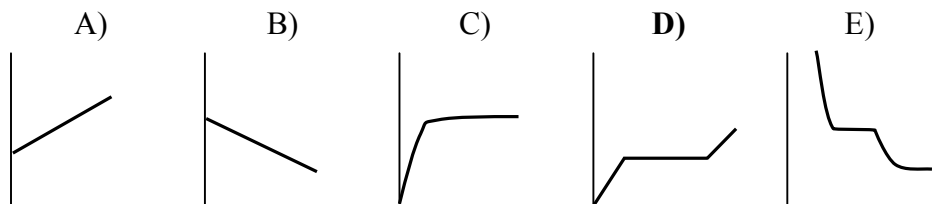
13) What phase(s) are present at the point (T₂, P₁)?

- A) solid
- B) liquid
- C) gas
- D) liquid and solid
- E) solid and gas**

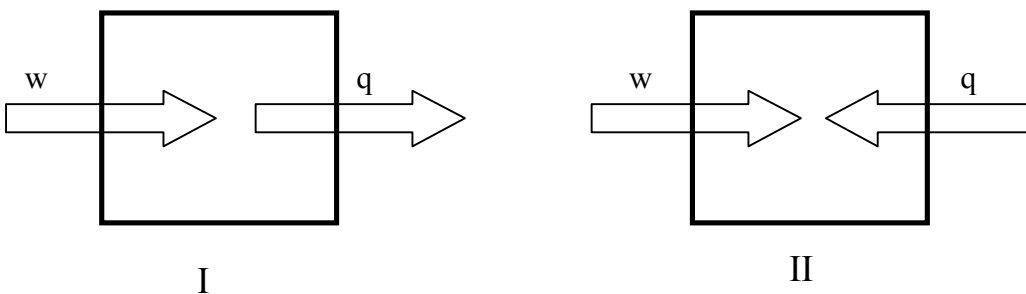
14) What will occur with an increase in temperature at constant pressure when starting from the point (T₁, P₁) ?

- A) Solid to gas phase change.**
- B) Solid to liquid phase change.
- C) Liquid to gas phase change.
- D) Liquid to solid phase change
- E) There is no phase change based on the data available.

15) Which plot best represents the system temperature (y axis) vs. joules of heat added (x axis) for the path described in the previous question?



Use the system diagrams below to answer the following questions 16 – 20.



16) Which diagram can represent an isothermal process?

- A) **I** B) II C) both D) neither

17) Which diagram can represent an adiabatic process?

- A) I B) II C) both **D) neither**

18) What is ΔE (J) for diagram I if $|w| = 2000$ J and $|q| = 1500$ J?

$$w = +2000, q = -1500 \quad \Delta E = 500$$

- A) -500 **B) 500** C) 3500 D) -4000 E) 4000

19) What is ΔE (J) when $|w| = 2000$ J and $|q| = 1500$ J for the two step process represented by the energy transfers in diagram I followed by those in diagram II?

$$\Delta E = (w_1 + q_1) + (w_2 + q_2)$$

$$(500) + (2000 + 1500) = 4000$$

- A) -500 B) 500 C) 3500 D) -4000 **E) 4000**

20) What is $\Delta E_{\text{surroundings}}$ (J) if $|w| = 2000 \text{ J}$ and $|q| = 1500 \text{ J}$ for the two step process represented by the energy transfers in diagram I followed by those in diagram II?

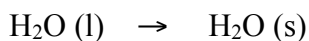
$$\Delta E_{\text{sys}} = -\Delta E_{\text{surr}}, \therefore -4000$$

A) -500 B) 500 C) -3500 **D) -4000** E) 4000

21) Which has a $S_f^\circ = 0$?

A) $\text{Cl}_2 (\text{g})$ B) $\text{H}_2\text{O} (\text{l})$ C) 12 C atoms D) $\text{N}_2 (\text{l})$ **E) none of these**

22) Which of the following row entries is correct for the freezing of water at -10°C ?



| | ΔH° | ΔS° | $-\Delta T\Delta S^\circ$ | ΔG° | Product-favored? |
|-----------|------------------|------------------|---------------------------|------------------|------------------|
| A) | - | - | + | - | Yes |
| B) | - | + | + | - | Yes |
| C) | + | - | - | + | No |
| D) | + | - | - | + | No |
| E) | + | + | - | + | No |

23) Is it possible for an ideal gas to absorb heat and NOT experience a change in temperature? **Mark all that apply.**

- A) no, heat and temperature are the same thing.
- B) yes, heat and temperature are the same thing.
- C) no, ideal gas processes are never isothermal.
- D) yes, ideal gas processes are always isothermal.
- E) yes, the system could also do work.**

24) For an exothermic reaction, K will increase when: **(Mark all that apply)**

- A) reactants are added.
- B) products are added.
- C) the volume decreases.
- D) the entropy of the universe increases.
- E) the temperature decreases.**

25) Which of the following intermolecular forces are present in a solution of pure water at STP?

- A) Hydrogen Bonding
- B) Dipole-Dipole
- C) Ion-Dipole
- D) Dispersion
- E) All of the above**

26) A 4.98 g sample of aniline ($C_6H_5NH_2$, molar mass = 93.13 g/mol) was combusted in a bomb calorimeter with a heat capacity of 4.25 kJ/°C. If the temperature rose from 29.5°C to 69.8°C, determine the value of $\Delta H^\circ_{\text{comb}}$ for aniline.

$$4.98 \text{ g aniline} / 93.13 \text{ g/mol} = 5.34 \times 10^{-2} \text{ moles}$$

$$69.8^\circ - 29.5^\circ = 40.3^\circ \quad \Delta T \times 4.25 \text{ kJ/C}$$

$$171.275 \text{ kJ} = \Delta H_{\text{surr}} = -\Delta H_{\text{rxn}}$$

$$-171.275 \text{ kJ} / 0.053 \text{ moles} = -3.2 \times 10^3 \text{ kJ/mol}$$

A) $+7.81 \times 10^3 \text{ kJ/mol}$

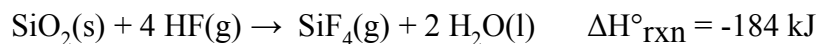
B) $-3.20 \times 10^3 \text{ kJ/mol}$

C) $+1.71 \times 10^3 \text{ kJ/mol}$

D) $-1.71 \times 10^3 \text{ kJ/mol}$

E) $-7.81 \times 10^3 \text{ kJ/mol}$

27) According to the following thermochemical equation, what mass of H_2O (in g) must form in order to produce 975 kJ of energy?



$$\Delta H = -184 \text{ kJ}, \quad -184 \text{ kJ} / 2 \text{ mol } H_2O$$

$$975 \text{ kJ} / -184 \text{ kJ} = 5.3 \times 2 \text{ mol } H_2O$$

$$10.6 \text{ mol} \times 18 \text{ g} = 191 \text{ g } H_2O$$

A) 68.0 g

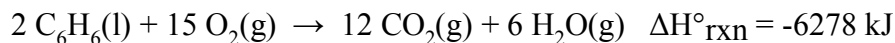
B) 102 g

C) 54.1 g

D) 191 g

E) 95.5 g

28) What volume of benzene (C_6H_6 , $d = 0.88 \text{ g/mL}$, molar mass = 78.11 g/mol) is required to produce $1.5 \times 10^3 \text{ kJ}$ of heat according to the following reaction?



$$1500 \text{ kJ} / 6278 \text{ kJ} = 0.239 \text{ mol equiv.}$$

$$\begin{array}{r} \times 2 \text{ benzene/equiv.} \\ \hline 0.48 \text{ mol benzene} \end{array}$$

$$.48 \text{ mol} \times 78.11 \text{ g/mol} \times 1 \text{ mL} / .88 \text{ g} = 42 \text{ mL}$$

A) 75 mL

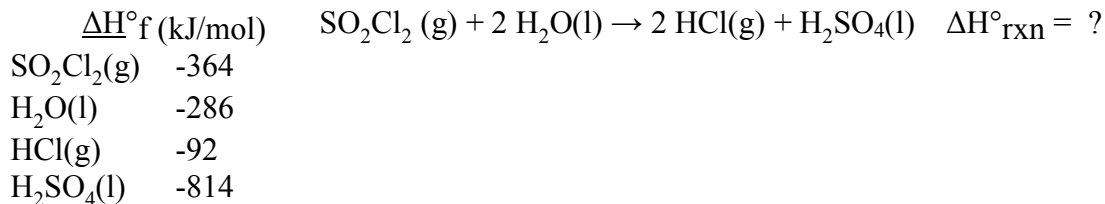
B) 37 mL

C) 21 mL

D) 19 mL

E) 42 mL

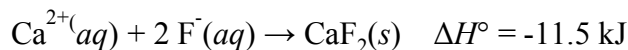
29) Use the ΔH°_f information provided to calculate $\Delta H^\circ_{\text{rxn}}$ for the following:



$$[2(-92) + (-814)] - [2(-286) + (-364)] = -62$$

- A) -256 kJ
- B) +161 kJ
- C) -62 kJ**
- D) +800. kJ
- E) -422 kJ

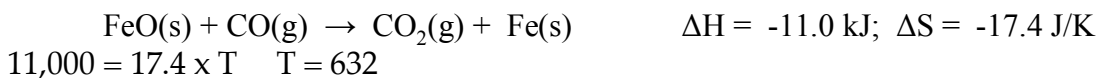
30) When 50.0 mL of 0.400 M $\text{Ca}(\text{NO}_3)_2$ is added to 50.0 mL of 0.800 M NaF, CaF_2 precipitates, as shown in the net ionic equation below. The initial temperature of both solutions is 23.0°C . Assuming that the reaction goes to completion, and that the resulting solution has a mass of 100.00 g and a specific heat of $4.18 \text{ J}/(\text{g} \cdot ^\circ\text{C})$, calculate the final temperature of the solution.



- A) 22.45°C
- B) 23.55°C**
- C) 24.10°C
- D) 24.65°C
- E) 25.02°C

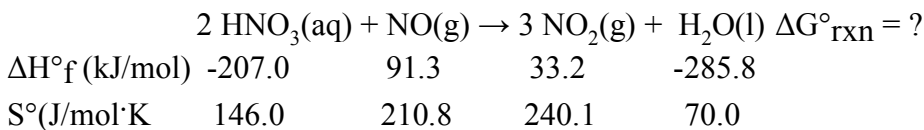
$$\begin{aligned} 0.05 \text{ L} \times 0.4 \text{ M} &= 0.02 \text{ mol } \text{CaF}_2 \text{ formed} \\ -11.56 \text{ kJ/mol} \times 0.02 \text{ mol} &= -0.23 \text{ kJ} \\ q_{\text{sys}} = -q_{\text{surr}} &= 0.23 \text{ kJ (temp. raise)} \\ 230 \text{ J} / 4.18 \text{ (J/gC)} / 100 \text{ g} &= +0.55^\circ\text{C} \end{aligned}$$

31) Above what temperature does the following reaction become nonspontaneous?



- A) 632 K**
- B) 298 K
- C) 191 K
- D) This reaction is nonspontaneous at all temperatures.
- E) This reaction is spontaneous at all temperatures.

32) Calculate the $\Delta G^\circ_{\text{rxn}}$ using the following information.



$$\Delta H = [-285.8 + 3(33.2)] - [91.3 + 2(-207)]$$

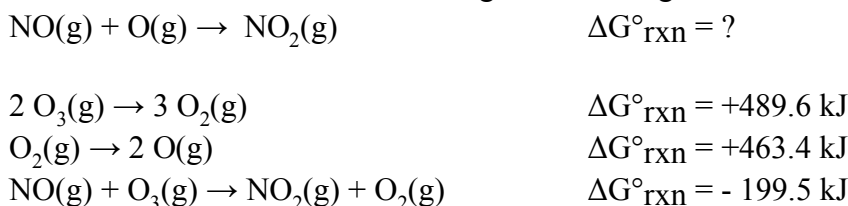
$$\Delta H = +136.5 \text{ kJ}$$

$$\Delta S = [3 \times 240.1 + 70] - [210.8 + 2(146)] = +287.5 \text{ J/K}$$

$$\Delta G = 136.5 \text{ kJ} - (298\text{K}) \times (0.2875 \text{ kJ/K}) = +50.8 \text{ kJ}$$

- A) -151 kJ
- B) -85.5 kJ
- C) +50.8 kJ**
- D) +222 kJ
- E) -186 kJ

33) Use Hess's law to calculate $\Delta G^\circ_{\text{rxn}}$ using the following information.



| | | |
|------------------------------|---|--|
| I | $\text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2$ | |
| II | $\text{O}_2 \rightarrow 2\text{O}$ | |
| III | $2\text{O}_3 \rightarrow 3\text{O}_2$ | |
| IV | $\text{NO} + \text{O} \rightarrow \text{NO}_2$ | |
| IV - I = | $\text{O}_2 + \text{O} \rightarrow \text{O}_3$ | |
| IV - I + II = | $2\text{O}_2 \rightarrow \text{O}_3 + \text{O}$ | |
| 2(IV - I + II) = | $4\text{O}_2 \rightarrow 2\text{O}_3 + 2\text{O}$ | |
| 2(IV - I + II) + III = | $\text{O}_2 \rightarrow 2\text{O} = \text{II}$ | |
| 2(IV - I + III) + III - II = | O | $\therefore \text{IV} = \frac{1}{2}(\text{III} - \text{II}) + \text{I} - \text{III}$ |
| | | $\text{IV} = \text{I} - \frac{1}{2}\text{III} - \frac{1}{2}\text{II}$ |

$$\text{IV} = -199.5 - \frac{1}{2}(463.4) - \frac{1}{2}(489.6) = -676$$

- A) +753.5 kJ
- B) +277.0 kJ
- C) -676.0 kJ**
- D) -1152.5 kJ
- E) -225.7 kJ

34) Choose the statement below that is TRUE.

- A) $K > 1$, $\Delta G^\circ_{\text{rxn}}$ is positive.
- B) $K < 1$, $\Delta G^\circ_{\text{rxn}}$ is negative.
- C) $\Delta G^\circ_{\text{rxn}} = 0$ at equilibrium.
- D) All of the above statements are true.
- E) None of the above statements are true.**

35) Determine the equilibrium constant for the following reaction at 655 K.



$$\Delta G = \Delta H - T\Delta S = -158 \text{ kJ} - (655)(-0.2199)$$

$$\Delta G = -13.9655 \text{ kJ} = -RT \ln K$$

$$2.56 = \ln K, \quad \therefore K = 13$$

A) 3.99×10^{12}

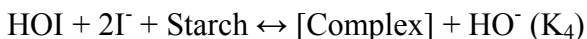
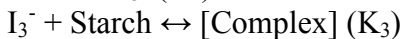
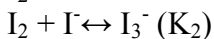
B) 13.0

C) 2.51×10^{-13}

D) 3.26×10^{-12}

E) 3.07×10^{11}

36) Using the equations below, which is the correct definition of K_4 ?



A) $K_4 = K_1 K_2 / K_3$

B) $K_4 = K_1 K_3 / K_2$

C) $K_4 = K_1 / K_2 K_3$

D) $K_4 = K_3 / K_1 K_2$

E) $K_4 = K_2 K_3 / K_1$

37) Which of the following gasses will have the largest deviation from ideal behavior?



A, C, and D all have strong intermolecular forces (hydrogen bond).

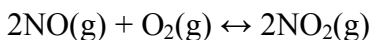
B, C, and E are all large atoms/molecules.

C has both.

38) Which statements are true? **Mark all that apply.** (From suggested problems, #47 in Ch. 17)

- A) $S^\circ \text{NaNO}_3(\text{s}) > S^\circ \text{NaNO}_3(\text{aq})$
- B) $S^\circ \text{Br}_2(\text{g}) > S^\circ \text{Br}_2(\text{l})$**
- C) $S^\circ \text{CH}_4(\text{g}) > S^\circ \text{C}_2\text{H}_6(\text{g})$
- D) $S^\circ \text{SiH}_4(\text{g}) > S^\circ \text{CH}_4(\text{g})$**
- E) $S^\circ \text{PCl}_3(\text{g}) > S^\circ \text{PCl}_5(\text{g})$

39) Consider the following reaction at 175 K



If the initial pressure of NO is 522 Torr, the initial pressure of oxygen is 421 Torr, and the total pressure at equilibrium is 748 Torr, what is K_p ? (From suggested problems, # 91 in Ch. 14)

$$748 = (522 - 2x) + (421 - x) + 2x$$

$$x = 195 \text{ Torr}$$

$$\text{NO} = 132 \text{ Torr} = 0.174 \text{ atm}$$

$$\text{O}_2 = 226 \text{ Torr} = 0.297 \text{ atm}$$

$$\text{NO}_2 = 390 \text{ Torr} = 0.513 \text{ atm}$$

$$K = (0.513)^2 / (0.174)^2 (0.297) = 29.34 \text{ atm}^{-1}$$

- A) 1.26 atm^{-1}
- B) 0.793 atm^{-1}
- C) $3.40 \times 10^{-3} \text{ atm}^{-1}$
- D) 29.3 atm^{-1}**
- E) $3.83 \times 10^4 \text{ atm}^{-1}$

40) Consider the following reaction:



A reaction mixture initially contains 0.56 atm CO_2 and 0.32 atm CO . Determine the equilibrium pressure of CO if K_p for the reaction at this temperature is 2.25 atm.

A) **0.83 atm**

B) 0.31 atm

C) 0.26 atm

D) 0.58 atm

E) 0.42 atm

$$K = \frac{[\text{CO}]^2}{[\text{CO}_2]} \quad 2.25 = \frac{[.32+2x]}{[.56-x]}$$
$$1.26 - 2.25x = 4x^2 + 1.28x + 0.2014$$

$$0 = 4x^2 + 3.53x - 1.157$$

$$x = \frac{-3.53 \pm (3.53^2 + 4 \times 4 \times 1.157)^{0.5}}{8}$$

$$x = -1.137, 0.254$$

↑
unrealistic, negative pressure

$$.32 + 2(0.254) = 0.83 \text{ atm}$$