1. (5%) A gas at 250K and 15 atm has a molar volume 12 per cent smaller than that calculated from the perfect gas law. Calculate the compression factor, Z under these conditions. (The gas constant, $R = 8.206\times10^{-2} L\,atm\,K^{-1}\,mol^{-1}$) (a) 0.72, (b) 0.88, (c) 0.94, (d) 1.12, (e) 1.24.

2. (5%) In the isothermal reversible compression of $5.2\times10^{-2}\,mol$ of a perfect gas at 260K, the volume of the gas is reduced to one-third its initial value. Calculate the work, w for this process. (a) $13J$, (b) $52J$, (c) $86J$, (d) $96J$, (e) $123J$.

3. (5%) For the reaction $C_2H_5OH(l)+3O_2(g)\rightarrow 2CO_2(g)+3H_2O(g)$, the standard reaction internal energy change, $\Delta_r U^\circ = -1373\,kJmol^{-1}$ at 298K. Calculate $\Delta_r H^\circ$. (a) $-1368\,kJmol^{-1}$, (b) $-1375\,kJmol^{-1}$, (c) $-1377\,kJmol^{-1}$, (d) $-1391\,kJmol^{-1}$, (e) $-1451\,kJmol^{-1}$

4. (5%) For a gas that follows the van der Waals gas law, $(p+a/V_m^2)(V_m-b)=RT$ with $a=1.352\,atmL^2\,mol^{-2}$ and $b=5\times10^{-2}\,Lmol^{-1}$, Calculate the molar internal energy change, ΔU_m for the isothermal reversible expansion of the gas from an initial volume of $1\,L$ to $24.8\,L$ at 298K. (a) $522\,Jmol^{-1}$, (b) $308\,Jmol^{-1}$, (c) $131\,Jmol^{-1}$, (d) $58\,Jmol^{-1}$, (e) $39\,Jmol^{-1}$.

5. (5%) Calculate the increase in entropy when $1\,mol$ of a monatomic perfect gas with the molar heat capacity at constant pressure, $C_{p,m}=5R/2$, is heated from 300K to 600K and simultaneously expanded from $30\,L$ to $50\,L$. (a) $4.2\,JK^{-1}$, (b) $8.4\,JK^{-1}$, (c) $12.9\,JK^{-1}$, (d) $16.9\,JK^{-1}$, (e) $20.7\,JK^{-1}$.

6. (5%) The fugacity coefficient of a certain gas at 200K and 50 bar is 0.72. Calculate the difference of its chemical potential from that of a perfect gas in the same state. (a) $-0.12\,kJmol^{-1}$, (b) $-0.27\,kJmol^{-1}$, (c) $-0.39\,kJmol^{-1}$, (d) $-0.55\,kJmol^{-1}$, (e) $-0.76\,kJmol^{-1}$.

7. (5%) When benzene freezes at 5.5°C its density changes from $0.879\,g\,cm^{-3}$ to $0.891\,g\,cm^{-3}$. Its enthalpy of fusion is $10.59\,kJ\,mol^{-1}$, Estimate the freezing point of benzene at $1000\,bar$. (a) 279.9K, (b) 281.8K, (c) 283.1K, (d) 284.5K, (e) 285.1K.

8. (5%) The solubility of AgBr is $2.6\,\mu mol\,kg^{-1}$ at 25°C. What is the emf of the cell $Ag|AgBr(aq)|AgBr(s)|Ag$ at that temperature? (Some standard electrode potentials at 298K:
$Ag^+ + e^- \rightarrow Ag \quad E^\circ = 0.8V$, and $AgBr + e^- \rightarrow Ag + Br^- \quad E^\circ = 0.071V$)
(a) $0.729V$, (b) $0.871V$, (c) $1.112V$, (d) $0.594V$, (e) $0V$.

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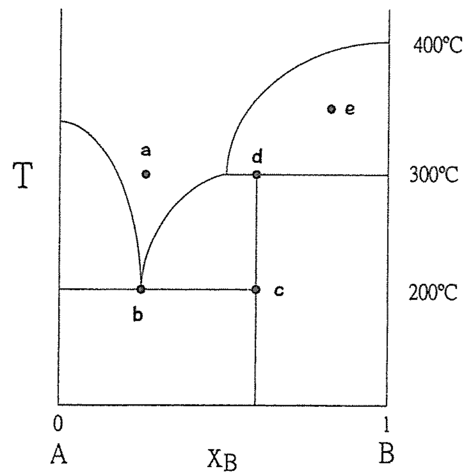
9. (5%) Indicate on the phase diagram below, the feature that denotes incongruent melting. (a) point a, (b) point b, (c) point c, (d) point d, (e) point e.



10. (5%) What is the criterion to determine the spontaneity of a reaction? (a) $dH_{S,P} \le 0$, (b) $dA_{T,P} \le 0$, (c) $dG_{T,S} \le 0$, (d) $dU_{P,V} \le 0$, (e) $dS_{G,P} \ge 0$. (H: the enthalpy; S: the entropy; A: the Helmholtz energy; G: the Gibbs energy)

11. (10%) Milk is pasteurized if it is heated to 63°C for 30 minutes, but if it is heated to 74°C it only needs 15 seconds for the same results. Find the activation energy of this pasteurization process.

12. (20%) The homogeneous reaction between sulfur vapor and methane has been studied in a small tubular reactor of 35.2 cm^3 volume at 1 atm and 600°C. The rate is expressed by a second-order equation. (atomic weight, S=32, C=12, H=1)

$CH_4 + 2\,S_2 \rightarrow CS_2 + 2\,H_2S$, $\quad r_{CS2} = k\,P_{CH4}P_{S2}$

The steady-state generation of CS_2 is 0.10 g in a 10-minute run. The CH_4 feed rate is 0.119 mole/hr. The S_2 feed rate is 0.238 mole/hr. The rates of H_2S and CS_2 are zero at entry of reactor. Assume that all species are ideal gases. (a) What is the rate of reaction, expressed in mole of CS_2 produced per hour per volume (cm^3). (b) Calculate the rate constant k when the reaction is carried out in this tubular reactor.

13. (20%) A process for the hydrodealkylation of toluene from petroleum stocks to produce benzene and methane has been developed. The hydrodealkylation occurs in the gas phase at high temperature and involves free radical. The free radical mechanism is believed to proceed by the sequence. Derive the reaction rate law for the rate of formation of benzene based on this mechanism

$$H_2 \xrightarrow{k_1} 2H\bullet$$
$$H\bullet + C_6H_5CH_3 \xrightarrow{k_2} C_6H_5\bullet + CH_4$$
$$C_6H_5\bullet + H_2 \xrightarrow{k_3} C_6H_6 + H\bullet$$
$$2H\bullet \xrightarrow{k_4} H_2$$

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