

**Name:** \_\_\_\_\_  
**MSC 409 Midterm Spring 2007 (100 points total)**

Circle your choice within the following statements, some of these also ask for explanations. Most are weighted 3 pts each.

1. Precipitation attributable to the collision-coalescence process is aided through the presence of (smaller, larger, is unaffected by size) cloud droplets.
2. The number of cloud droplets formed from a given amount of aerosol is (greater, less, unaffected) for stronger updrafts, all else remaining equal.
3. Supercooled water droplets over land are (smaller than, larger than, the same size as) supercooled water drops over the ocean. EXPLAIN.
  
4. Supercooled droplets over land are (more, less, indifferently) likely to freeze than marine supercooled water droplets. EXPLAIN.
  
5. Snowflakes are most likely to form at (-25C, -15C, -5C).
6. Effective ice nuclei include (dust, sea salt, sulfates, clay). Circle all that apply.
7. Collisions between drops are most likely to lead to coalescence if the drops are (similarly sized, of different sizes).
8. Aerosols serving to nucleate cloud droplets are typically (1/1000, 1/100, 1/10, same size as) the size of a typical cloud droplet.
9. Diffusional (vapor-driven) growth is (more rapid, less rapid) for ice than for liquid at -10 C, all else equal.
10. Freezing of pure water drops occurs at approximately (-10 C, -20C, -30C, -40C).
11. Ice nuclei concentrations (increase, decrease, stay the same) as a function of supersaturation over ice.
12. The fall speed of small drops depends (more strongly, less strongly, indifferent to) their radius than do large drops.
13. At what temperature does the saturation vapor pressure excess of water over ice reach its maximum ? ( below -30 C, above -30 C)
14. Which of these elements is necessary for lightning ? (ice needles, ice splintering, super-cooled water, graupel, liquid water)

SHORT ANSWERS:

15. Write down the condensation (diffusional) growth eqn, in terms of  $dr/dt$ .
  
16. 2 drops of different initial radius grow exclusively through diffusional growth. Using your equation from question 15 show how the difference between the radii of the 2 drops relate to each other at a later time, in terms of the initial difference. (Hint: integrate).

17. Write down the collisional growth eqn. in terms of  $dr/dt$ .
  
18. Draw the charge distribution within a cloud likely to produce lightning.
  
  
  
  
  
  
  
  
  
  
19. Why do holes in super-cooled clouds produced by jets typically not extend by more than 10 km in diameter ?
  
  
  
  
  
  
  
  
  
  
20. Draw a Kohler curve. Label and explain the curvature effect, and the solute effect. Label both axes.
  
  
  
  
  
  
  
  
  
  
21. Draw another Kohler curve on top of the one shown in #20 corresponding to water with a 10X solute concentration as the one in #20
  
  
  
  
  
  
  
  
  
  
22. What acts as a nucleus in homogeneous nucleation ?
  
  
  
  
  
  
  
  
  
  
23. How many cloud drops of radius 10 micron have to combine to form a raindrop of radius 1 mm ?

24. If the initial cloud drop concentration was  $100 \text{ cm}^{-3}$  in problem 23, what would be the concentration of raindrops (assuming all cloud drops combine) ?
25. What was the initial spacing between the cloud drops in question 23, and what is it now for the raindrops ?
26. Why do hurricanes have relatively little lightning while Florida is the lightning capital of the US ?
27. Why does nucleation of liquid on a soluble nucleus require less supersaturation than on an insoluble nucleus ?

A numerical problem: (16 pts)

A hailstone consists completely of ice at the 0 C isotherm. As it falls into warmer air, which has a lapse rate of 6.5 C/km, it experiences a drag force  $F_{\text{drag}} = 6\pi\eta vR$  where  $\eta$  is the dynamic viscosity of the air; assume the hailstone reaches its terminal velocity instantaneously. As the hailstone falls it collects droplets that have the temperature of the air at that level, and that contribute to the melting of the hailstone as the droplets cool down to 0 C.

Assume the size of the hailstone (water +ice) stays the same, and a mean collection efficiency of 0.75. Assuming the density of ice is  $\frac{1}{2}$  the density of water, the radius of the hailstone is 1 cm and the LWC of the cloud is  $0.7 \text{ g/m}^3$  everywhere below the freezing level.

Useful constants: latent heat of fusion at 0 Celsius:  $L=3.34 \times 10^5 \text{ J/kg}$ ; specific heat of liquid water at 0 C:  $4218 \text{ J}/(\text{deg} \cdot \text{kg})$ ; dynamic viscosity of air=  $1.7 \cdot 10^{-3} \text{ kg}/(\text{m} \cdot \text{s})$ ; density of water =  $10^3 \text{ kg/m}^3$

1. What is the terminal velocity of the hailstone ?
  
2. What does the collision-collection equation look like for this problem ?

3. What does the heat transfer equation between the ice and collected water look like as a function of the distance below freezing level ?

4. Solve for how long it takes to melt the hailstone completely, and how far below the freezing level the hailstone just completes its melting.



*"We'll feel pretty silly if it's downgraded to a tropical storm."*



*"I'm an optimist. I have every confidence that global warming will be nullified by nuclear winter."*

